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Transactions

of the

Illinois State Academy of Science

Volume 59
No. 1
1966

Springfield, Illinois

TRANSACTIONS of the ILLINOIS STATE ACADEMY OF SCIENCE

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14

TRANSACTIONS

OF THE

ILLINOIS STATE ACADEMY OF SCIENCE

VOLUME 59 - 1966 No. 1

Illinois State Academy of Science

affiliated with the

Illinois State Museum Division

Springfield, Illinois

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

Otto Kerner, *Governor*

March 15, 1966

CONTENTS

Comparison of Some Amino Acid Mixtures and Proteins for the Diet of Drosophila Melanogaster.
By B. W. Geer 3
Two New Series of *Oecetis* Occurring in Eastern North America (Trichoptera, Leptoceridae).
By Herbert H. Ross 11
Origin of Man and Culture
By Thorne Deuel 15
The Minimal Society
By Thorne Deuel 20
Bluff Prairie Vegetation and Soil Texture
By Marilyn K. Bland and Paul D. Kilburn 25
The Illinois Taxa of *Paspalum*
By B. J. Verts and Robert H. Mohlenbrock 29
Radiocarbon Dates from Altonian and Twocreekan Deposits at Sycamore, Illinois
By John P. Kempton 39
Petrography of Devonian Phosphates of Indiana
By Brian J. Bluck 43
An Iodine-Methyl Sulfoxide Precipitate
By Rebecca Reid and Boris Musulin 48
The Constitutive Nature of the Polymer Bond
By Boris Musulin 51
Microdetermination of Sulfur and Halogens in Nonvolatile Substances in Solution by the Schoniger Flask Method
By Clara McGrew and Cecil H. VanEtten 58
A First Iterate for Association Constants
By Borius Musulin 62
The Solubility of Barium Monofluorophosphate
By David G. Rands and Roy E. Bruns 72
News and Comments 72
Occurrence of the Intact Spermatozoa in Spontaneous Ejaculations of Isolated Male Guinea Pigs
By Jan Martan 78
Range Extension of the Least Weasel and Pigmy Shrew in Illinois
By Paul W. Parmalee and Edward A. Munyer 81
New Algal Records for Knox County, Illinois
By Kenneth L. Weik 83
Notes on the Flora of Several Illinois Counties
By Donald R. Windler 85
Myxomycetes in Southern Illinois
By George W. Folkerts and Robert H. Mohlenbrock 87
Some Aquatic Phycomycetes from Pine Hills
By Robert J. Bandoni and John D. Parsons 91
The Averaging Process for Iterative Association Constants
By Boris Musulin 95

COMPARISON OF SOME AMINO ACID MIXTURES AND PROTEINS FOR THE DIET OF DROSOPHILA MELANOGASTER

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ABSTRACT.—The nutritive values of several proteins for the development of *Drosophila melanogaster* as measured by viability, adult size, and developmental time exceeded that of amino acid mixtures. The descending order of effectiveness of the test proteins was soy, lactalbumin, casein, supplemented gluten and peanut meal. One of the test amino acid mixtures supported development better than any which has been employed by others in previous studies. Of the nitrogen sources tested, the best development was observed when a mixture of acid hydrolyzed and intact casein was fed.

Drosophila melanogaster is among the insect species which have been cultured on diets containing amino acids as the sole source of nitrogen (Schultz, St. Lawrence and Newmeyer, 1946; Hinton, Noyes and Ellis, 1951). However, *D. melanogaster* larvae do not develop as well on amino acid diets as they do on intact protein diets (Sang, 1956, 1959, 1962; Geer, 1963). These data coupled with the results of experimentation on other insect species (Vanderzant, 1958; Cheldelin and Newburgh, 1959; Leclercq and Lopez-Francos, 1964; Naylor, 1964) indicate that nonhydrolyzed protein has a nutritive value for insect development not found in its constituent amino acids. An exception to this observation, which may possibly be extended to insects in general, is the onion maggot which develops more rapidly on an amino acid diet (Friend, Salkeld and Stevenson, 1959).

Investigators studying the growth-stimulating value of amino acids in rat diets have made conflicting observations. Sauberlich (1961) presented data which indicate that amino acid diets can equal diets of intact protein in nutritional value. However, reports by Breuer et al. (1963) and Salmon (1964) do not agree, but instead indicate that intact protein is superior for growth to amino acid mixtures in the rat diet. Thus, the majority of the studies of insect nutrition and rat nutrition agree on the superior dietary qualities of intact protein.

The present investigation compares the nutritive values of several intact protein and amino acid diets for *D. melanogaster* development. It also examines the relationship of the degree to which dietary protein has been hydrolyzed to its adequacy for development. The term development as used here includes not only the period of rapid larval growth but also the ability of the larva to metamorphose.

Methods and Materials

To avoid strain-specific nutritional differences, the larvae tested in this study were obtained by a three-way cross of the Canton-S, Riverside and Oregon-R strains. These strains had been made homozygous by a marker-inversion mating scheme (Geer, 1964). Canton-S females were crossed to Riverside males and the heterozygous female offspring were mated to Oregon-R males. Using the techniques described by Geer (1963) and Geer and Vovis (1965), eggs were collected from the females of the latter cross, sterilized and inoculated by aseptic methods onto the test media. Cultures were kept at 23.8± 1.1 °C. and 50% relative humidity with a 10 hour light to 14 hour dark day. Results of the experiments were assessed by comparing the larval developmental times, defined as days from egg to pupation; the larval viabilities, determined by the percentage of larvae to pupate and to reach adulthood; and the adult sizes, measured by female dry weight. These variables are dependent upon the larva's ability to utilize its diet to develop from a newly hatched larva to the adult or imago stage.

The amino acid test mixtures are given in Table 1, and the other nitrogen test sources are indicated with the ap-

Table 1.—Amino acid test mixtures. Individual amino acids are given in mg of amino acid per 100 ml of medium.

Mixture	A	B	C	D	E	F	G
L-Alanine	108.5	152.0	60.0	.....	.....	.....	.....
L-Arginine·HCl	55.9	179.0	80.0	80.0	80.0	80.0	80.0
L-Aspartic acid	122.1	198.0	60.0	.....	.....	.....	.....
L-Cystine	48.0	31.0	30.0	30.0	30.0	30.0	30.0
L-Glutamic acid	441.8	300.0	400.0	840.0	1,000.0	1,200.0	1,200.0
Glycine	174.5	110.0	40.0	40.0	40.0	40.0	40.0
L-Histidine·HCl	48.4	93.5	100.0	100.0	100.0	100.0	100.0
L-Hydroxyproline	38.8	.....	.....	.....	.....	.....	.....
DL-Isoleucine	126.0	119.0	300.0	300.0	250.0	200.0	300.0
L-Leucine	234.5	166.0	200.0	200.0	175.0	150.0	200.0
L-Lysine·HCl	133.7	227.0	190.0	190.0	170.0	150.0	190.0
DL-Methionine	33.9	36.0	80.0	80.0	80.0	80.0	80.0
DL-Phenylalanine	100.8	81.0	130.0	130.0	130.0	130.0	130.0
L-Proline	168.6	110.0	50.0	.....	.....	.....	.....
DL-Serine	126.0	116.0	50.0	.....	.....	.....	.....
DL-Threonine	75.6	127.0	200.0	200.0	200.0	150.0	200.0
L-Tryptophan	174.5	30.0	50.0	50.0	50.0	50.0	50.0
L-Tyrosine	124.0	91.0	80.0	80.0	80.0	80.0	80.0
DL-Valine	135.5	134.0	280.0	280.0	220.0	200.0	280.0

propriate data. Unless otherwise noted, the total nitrogen supplied by protein or amino acids in all test diets was 0.30 g per 100 ml of medium. The remainder of the diet consisted of yeast ribonucleic acid, sucrose, cholesterol, choline, B- vitamins and salts in the concentrations given by Geer and Vovis (1965). Amino acid test mixture A is essentially the same as those employed by Schultz et al. (1946) and Hinton et al. (1951); B resembles the amino acid composition of yeast protein; and C and D contain amino acids in the same proportions as found in amino acid mixtures used in rat diets by Salmon (1964).

Vitamin-free casein was obtained from the California Corporation for Biochemical Research, Assay Protein C-1 (soy) from Skidmore Enterprises and extracted peanut meal from the General Biochemical Corporation. Inorganic constituents were purchased from the Fisher Scientific Corporation. All other nutrients and vitamins were obtained from the Nutritional Biochemicals Corporation.

Results

The nutritive values of amino acid mixtures A-D are indicated in Table 2. D was a superior and C an inferior nitrogen source. Larvae cultured on D had a significantly shorter developmental period and exhibited higher rates of pupation and emergence than larvae cultured on A or B. There was no size difference between adults grown on A and D, but adults grown on B were much reduced in size.

The concentration of L-glutamic acid was much greater in D than in A, B or C. Mixtures E, F and G were formulated to test the effects of increasing the concentration of L-glutamic acid above the level in D. In E and F the total nitrogen content was maintained at 0.30 g per 100 ml of medium by reducing the concentrations of DL-isoleucine. L-leucine, L-lysine and DL-threonine as the concentration of L-glutamic acid was increased. In G the concentrations of all amino acids were maintained at the same level as in D while the concentration of L-glutamic acid was increased; consequently, the nitrogen content of G was 0.33 g per 100 ml of medium. Increasing the concentration of L-glutamic acid at the expense of the essential amino acids had little effect on viability but it lengthened the developmental time (Table 3). Adult size was also decreased. Increasing the L-glutamic acid concentration, but not at the expense of other amino acids, decreased adult size slightly and lengthened the developmental time by 0.6 day.

Table 2.—Development of larvae on amino acid diets.

Test mixture	Original no. of larvae	% Larvae to pupate	% Larvae to become adults	Developmental time ±S.D. (days)	Female dry weight (mg X 100)
A	1872	72.0	60.1	15.0 ±2.1	23.1
B	1640	48.7	34.3	18.5 ±3.6	14.5
C	1228	7.3	2.5	23.5 ±2.4	.....
D	1965	92.1	86.9	12.3 ±1.4	23.1

The influence of the degree of hydrolysis of the protein on development was studied by feeding larvae either intact casein, enzyme digested casein, acid hydrolyzed casein or a mixture of acid hydrolyzed and intact casein (Table 4). Larvae cultured on intact casein, enzyme digested casein or the acid hydrolyzed-intact casein mixture were equally viable and were more viable than larvae cultured on supplemented acid hydrolyzed casein. Those larvae which were grown on the acid hydro-

TABLE 3.—Development of larvae on amino acid diets with different concentrations of L-glutamic acid.

Test mixture	Original no. of larvae	% Larvae to pupate	% Larvae to become adults	Developmental time ±S.D. (days)	Female dry weight (mg X 100)
D	1008	96.0	89.3	13.1 ±1.4	21.8
E	1312	93.7	89.7	13.2 ±1.6	18.6
F	1107	90.3	83.7	14.4 ±1.2	18.4
G	1207	91.3	87.9	13.7 ±1.5	18.6

TABLE 4.—Development of larvae on intact, enzyme digested, and acid hydrolyzed casein.

Nitrogen source	Original no. of larvae	% Larvae to pupate	% Larvae to become adults	Developmental time ±S.D. (days)	Female dry weight (mg X 100)
Intact	686	93.7	85.6	8.8 ±1.0	39.9
Enzyme digest	704	93.0	86.6	9.3 ±0.6	28.7
Acid hydrolysate[1]	733	75.3	72.0	15.0 ±1.5	25.4
Acid hydrolysate + intact[2]	729	96.3	84.4	7.4 ±0.6	37.3

[1] Supplemented with 50 mg of L-tryptophan and 30 mg of L-cystine per 100 ml of medium.
[2] Supplemented with 25 mg of L-tryptophan per 100 ml of medium.

lyzed-intact casein mixture developed more rapidly than larvae fed the other test diets. The second most rapid larval development was on intact casein. The rate of development was slower with enzyme digested casein and slowest with supplemented acid hydrolyzed casein. Adult size was correlated with the length of the larval growth period. The acid hydrolyzed-intact casein mixture and the intact casein diets yielded the largest adults and the enzyme digested casein and acid hydrolyzed casein diets were less effective in this respect.

The optimal ratio of intact casein to acid hydrolyzed casein in the larval diet was determined by feeding ratios of 1 to 9, 3 to 7, 1 to 1, 7 to 3, and 9 parts of dietary nitrogen in the form of intact casein to 1 part of dietary nitrogen supplied as acid hydrolyzed casein (Table 5). Using developmental time and larval viability as the criteria, 7 parts of intact casein to 3 parts of acid

hydrolyzed casein was the optimal ratio. In terms of adult size, intact casein was superior to the acid hydrolyzed-intact casein mixtures.

The nutritional qualities of proteins other than casein were studied (Table 6). The larvae grew much more rapidly and the adults were larger when fed soy

TABLE 5.—Development of larvae on mixtures of acid hydrolyzed and intact casein.

% Nitrogen supplied as acid hydrolyszed casein[1]	Original no. of larvae	% Larvae to pupate	% Larvae to become adults	Developmental time ±S.D. (days)	Female dry weight (mg X 100)
0	550	93.8	69.5	8.3 ±1.0	41.4
10	633	91.4	79.2	8.0 ±0.9	35.3
30	674	96.6	86.0	7.3 ±0.7	33.7
50	606	97.1	82.3	7.7 ±0.7	36.3
70	551	95.6	84.0	8.6 ±0.8	32.7
90	604	94.8	81.2	9.1 ±0.6	25.2
100	725	92.0	77.9	9.3 ±1.0	22.8

[1] The diets were supplemented with L-tryptophan in amounts proportional to the amount of acid hydrolyzed casein contained in each diet. In addition, the diet containing only acid hydroloyzed casein was supplemented with 30 mg of L-cystine, 20 mg of DL-phenylalanine, and 20 mg of L-histidine • HC1 per 100 ml of medium.

TABLE 6.—Development of larvae on several protein diets.

Protein	Original no. of larvae	% Larvae to pupate	% Larvae to become adults	Developmental time ±S.D. (days)	Female dry weight (mg X 100)
Lactalbumin	1016	97.2	93.0	9.2 ±0.7	35.2
Peanut meal	972	85.7	83.0	12.3 ±1.3	36.0
Soy	1025	87.2	84.7	7.3 ±0.7	48.2
Gluten[1]	1110	87.2	84.9	8.6 ±0.8	34.7

[1] Supplemented with 50 mg L-glutamic acid, 30 mg of L-histidine • HC1, 100 mg of L-lysine • HC1, 30 mg of DL-threonine, and 20 mg of DL-valine per 100 ml of medium.

protein. However, viability of larvae fed lactalbumin was greater than that of the larvae fed the other proteins. The viabilities of larvae fed peanut meal and supplemented gluten were equal to the viability of soy-fed larvae, but less than lactalbumin-fed larvae.

Discussion

Glutamic acid appears to be of primary importance in the diet of *D. melanogaster* larvae. This is evidenced by the inferior nutritive value for development of amino acid test mixture C. Except for a lower glutamic acid concentration, C includes a greater number of nonessential amino acids than D. Apparently, glutamic acid does more than replace nonessential amino acids in diet D. Also, reductions of the concentrations of four essential amino acids in E, F and G had little effect on development when glutamic acid was increased. These observations on the development of larvae fed amino acid mixtures suggest that glutamic acid, in addition to its role in the synthesis of nonessential amino acids, has a sparing effect on the nutritional requirements for the essential amino acids. A glutamic acid sparing effect has been observed, in fact, in the nutrition of several insects. Naylor (1963) found that glutamic acid can partially replace essential amino acids in the diet of *Tribolium confusum*. Hodgson, Cheldelin and Newburgh (1956) showed that either aspartic acid or glutamic acid is required in the diet of *Phormia regina*. The suggestion of Hinton (1959) that glutamic acid can substitute for glycine in the diet of *D. melanogaster* agrees with the present observations.

Judgment of the adequacy of a protein for development depends upon the criteria which are used. For example, when larval developmental time is used as the criterion, soy, casein, supplemented gluten, lactalbumin and peanut meal are effective as dietary nitrogen sources in that descending order. Lactalbumin is the superior protein if larval viability is the criterion. If the protein diets are judged by their effect upon adult size, the descending order of dietary effectiveness is soy, lactalbumin, supplemented gluten, casein and peanut meal. The use of a number of criteria, which is perhaps the best approach, indicated that the sequence of effectiveness is soy, lactalbumin, casein, supplemented gluten and peanut meal in that order. That soy protein outranks lactalbumin and casein for the development of Drosophila agrees with the results of previous work with protein hydrolysates (Geer, 1963) on *D. melanogaster*.

Experimental data are consistent with the concept that amino acids do not support insect development as well as intact proteins do. This is true for a variety of insects. Naylor (1964) found that four different proteins had a development-accelerating effect for *T. confusum*. Vanderzant (1958) showed that acid hydrolyzed casein was inferior to intact casein in the diet of *Pectinophora gossypiella*. Similar observations have been made for *P. regina* (Cheldelin and Newburgh, 1959) and *Tenebrio molitor* (Leclercq and Lopez-Francos, 1964). To possibly explain the intact protein effect, Naylor (1964) has suggested that there may be some dietary value in peptide linkages or that there may be special peptides in certain pro-

teins which stimulate insect development. There is no conclusive evidence for either of these hypotheses.

The current experimentation indicates that a source of free amino acids may contribute to the nutritive value of a diet containing an intact protein. The evidence is supplied by the observation that development is more rapid and survival greater on a diet containing a mixture of acid hydrolyzed and intact casein than on one containing intact casein alone. Before any generalizations can be made, however, the work needs to be repeated with different proteins and also with other organisms.

Much effort has been directed toward the replacement of intact protein with amino acid mixtures in the diets of many organisms. The pertinent literature has been reviewed by Almquist (1951) and Greenstein and Winitz (1961). *D. melanogaster* belongs to the growing list of organisms for which intact dietary protein has been found to be superior to amino acid mixtures.

The fact that the development of *D. melanogaster* fed amino acid mixture D surpassed that of larvae fed mixture A is of some importance. Since A and variations thereof have been used when amino acid mixtures have been employed in previous studies of Drosophila nutrition, the superiority of D provides Drosophila research workers with a better amino acid diet for nutritional and biochemical investigations.

Acknowledgments

I am indebted to Mr. G. F. Vovis for his technical assistance. I would also like to acknowledge the financial support of National Science Foundation Grant GB-2239.

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Manuscript received June 15, 1965.

TWO NEW SPECIES OF *OECETIS* OCCURING IN EASTERN NORTH AMERICA (TRICHOPTERA, LEPTOCERIDAE)

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ABSTRACT.—Two new species of caddisflies occurring in eastern North America resemble *Oecetis inconspicua* (Walker) to a remarkable degree: *O. nocturna* from Ark., D. C., Ill., Ind., Mo., Okla., Penn., and Tenn.; and *O. ditissa* from Ill., Ind., Ohio, and Tenn. Illustrated keys differentiate these three species.

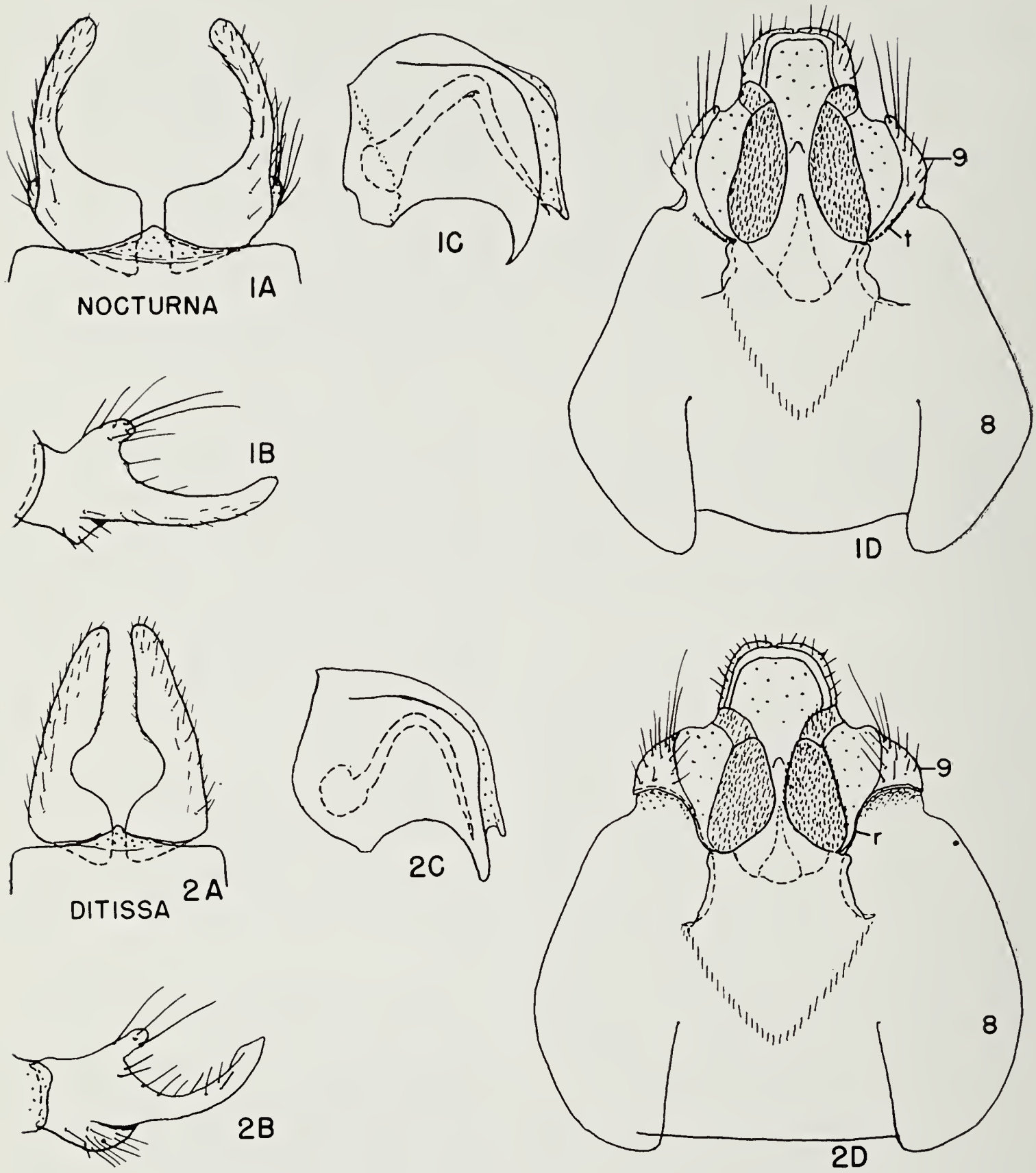
Among the more abundant elements of the midwestern caddisfly fauna are members of the genus *Oecetis*, whose species are long and slender, and have unusually long antennae. Most of the species are colored alike—yellowish brown with some obscure spotting. Diagnostic characters are to be found in the male and female external genitalia. Two midwestern members of the genus appear to be new to science and are here formally named.

The two species described in this paper are remarkably similar to *Oecetis inconspicua* (Walker), and it is likely that all three species are masquerading under this name in many collections. Characters to differentiate the three are given following the new descriptions. Unlike the transcontinental range of *O. inconspicua*, the ranges of the two new species appear to be restricted to the central part of the eastern temperate deciduous forest. From central Illinois south through Tennessee and from western Arkansas to Washington, D. C., all three species may occur in the same locality and in some instances have been taken together in the same light trap. The two new species have not been reared but it should be assumed that their larvae may be extremely similar to those of *O. inconspicua.*

Types described in this paper are deposited in the collection of the Illinois Natural History Survey except as noted. Illustrations are of the holotypes and allotypes, respectively.

Oecetis nocturna, new species

Male.—Length from tip of head to end of folded wings, 9 mm. Color brown with a reddish cast, the ventral areas of body and the legs lighter, almost straw color. Wings also light brown with a distinct darker bar across the cord. General structure typical for genus. Genitalia, Fig. 1 *A-C*, similar in general shape to those of *O. inconspicua* (Walker), diagnostic characters being present in the claspers and the aedeagus. Cerci, tenth tergite, and shape of ninth segment as in *O. inconspicua.* Clasper with a narrow profile; mesal aspect with a broad base tapering rapidly to an almost tubular long apical portion; the bases of the two claspers almost meeting on the meson and slightly overlapped by a small, wide, membranous projection of the eighth sternite. Aedeagus deep and



FIGURES 1, 2.—Genitalic structures of *Oecetis* species. *A*, *B*, male claspers, ventral and lateral aspects, respectively; *C*, aedeagus, lateral aspect of left side; *D*, female terminalia, ventral aspect. 8, 9, eighth and ninth segments, respectively. *r*, *t*, ventral ridge and thickening along posterior margin of ninth segment.

in general somewhat ovoid, its apex projecting ventrally into a down-pointed beak whose tip is pointed in posterior view; internal curved spine large and heavily sclerotized.

Female.—Length 8.5 mm. Color and general structure similar to male. Sides of ninth segment tapering ventrally to narrow points that join the bases of the subgenital lobes, Fig. 1 *D*. Ventral face of each subgenital lobe elongate and covered with a dense mass of short spines, the anterior end of each lobe joined to smooth triangular area of eighth sternite by a short, arcuate flange. Spermatheca well defined, its base slightly trianguloid, with a prominent anteroventral slender sclerotized process.

Holotype male, *allotype* female, and one male and one female *paratypes*.—Hollister, Mo., May 16, 1938, at light, Mrs. Vitae Kite. *Paratypes*. — ALA-

BAMA: Collinsville, June 20, 1960, at light, H. B. Cunningham, one male; Columbiana, July, 1941, C. M. Wetzel, two males, one female; ARKANSAS: Mt. Pine, June 5, 1937, H. H. Ross, one male; DISTRICT OF COLUMBIA: Washington, at light, May 31, 1956, C. A. Ross, one male; ILLINOIS: Benton, June 10, 1946, H. H. Ross, two males; Carbondale, May 6, 1938, at light, Frison and Ayars, one male; LaRue, McCann School, May 26, 1939, Burks and Riegel, one male, one female; Meredosia, May 14, 1934, Frison and Ross, one male; Quincy, near Cave Spring, July 6, 1939, Mohr and Riegel, two males, three females; St. Marie, September 11, 1956, Ross and Selander, two males; Urbana, July 22, 1958, light trap, R. Klatt, one male; Ziegler, August 21, 1933, J. Karlovich, one female; INDIANA: 2 miles east of Loogootee, at light, August 5, 1958, F. Schmidt, one female; Rogers, September 8, 1936, at light, Ross and Burks, six males; Shoals, White River, September 10, 1936, Ross and Burks, three males; MISSOURI: Hollister, June 5, 1938, Mrs. Vitae Kite, three males; Hollister, July 14, 1938, Mrs. Vitae Kite, three males; OHIO: Cambridge, September 13, 1936, T. H. Frison, one male; OKLAHOMA: Mt. Fork River, Hochatown, May 6, 1939, R. and K. Weddle, two males; Reagan, Pennington Cr., October 15, 1937, K. and R. Weddle, eight males; PENNSYLVANIA: Willow Hill, at light, June 8, 1959, Ross and Ross, two males; TENNESSEE: Jackson, May 13, 1957, light trap, Ross and Stannard, two males; Perryville, small stream, May 21, 1959, Ross and Stannard, one female; Springfield, May 13-27, 1957, light trap, Ross and Stannard, four males (one abdomen only).

Oecetis ditissa, new species

Male.—Lenth, color, and general structure similar to the preceding species. Genitalia, Fig. 2*A-C*. similar in general shape to those of *O. inconspicua* (Walker), diagnostic characters being present in the claspers and the aedeagus. Clasper profile with a moderately broad bamse, a dorsal thumb-like projection, and a long curved apical arm; mesal aspect broad, the mesal margins deeply incised and the apical portion wide and flat; the bases of the two claspers close together on meson, separated by only a small membranous projection of the ninth sternite. Aedeagus short and deep, its apex bent ventrally and forming a fairly long narrow beak; internally there is a stout, heavily sclerotized, twisted rod.

Female.—Length 8.5 mm. Color and general structure similar to male. Sides of ninth tergite tapering ventrally to narrow points that join the bases of the subgenital lobes, Fig. 2 *D*. From the base of each subgenital lobe arises a short anterior flange and another sinuate thin flange that proceeds posteriorly and curves laterally around the ninth segment; this latter flange is also the posterior border of a marked concavity. Spermatheca well defined, its anterior margin ovoid.

Holotype male, *allotype* female, and one male and one female *paratypes*.—Grand Tower, Jackson County, Illinois, May 30, 1935, at lights, H. H. Ross and C. O. Mohr. *Paratypes*.—ILLINOIS: LaRue, McCann School, May 26, 1939, Burks and Riegel, five male, three female; Libertyville, July 18, 1938, Burks and Boesel, one female; Quincy, near Cave Spring, July 6, 1939, Mohr and Riegel, three males; Urbana, July 8, 1930, H. H. Ross, one female; Urbana, June 29, 1958, at light, R. Klatt, one male; Urbana, August 22, 1958, light trap, R. Klatt, two males; Urbana, August 1-5, 1959, one male; INDIANA: Hovey Lake, Ent. Recon. Stn. 1, July 31-October 3, 1958, sixteen males, seven females; Jeffersonville, July 7, 1957, light trap, F. Schmidt, one male; 2 miles east of Loogootee, at light, August 5, 1958, F. Schmidt, one male; OHIO: Englewood, Stillwater River, July 31, 1939, T. H. Frison and T. H. Frison, Jr., one male, two females; TENNESSEE: Alcoa, May 6, 1957, light trap, two males; Columbia, May 6 and 13, 1957, light trap, two males; Greeneville, April 29-May 27, 1957, light trap, nine males (two, abdomens only), two females (abdomen only); Jackson, May 13-20, 1957, light trap, three males; Loretto, May 13, 1957, light trap, one male; Springfield, May 13-27, 1957, light trap, seven males (one, abdomen only); Sweetwater, May 6, 1957, two males.

Diagnosis

In existing keys both of these new species will key to *Oecetis inconspicua*. In the key given by Ross (1944, p. 237), males of the two new species will key readily to couplet 9. The following couplets will separate

the males of *O. inconspicua, ditissa,* and *nocturna,* and the related *O. immobilis* (Hagen):

9. Aedeagus considerably longer than deep, with a large, ventral, preapical beak (Ross 1944, Fig. 823*A*) ..... *immobilis* (Hagen)
Aedeagus very deep, almost as deep as long, with a ventral beak of various proportions but always near apex, Figs. 1*C*, 2*C*..... 9A

9A. Ventral beak of aedeagus short; apical margin of ninth segment forming a sclerotized rounded or truncate lobe between the bases of the claspers (Ross 1944, Figs. 824*A*, *B*); the process of the ninth sternite may be smaller than in this figure .... *inconspicua* (Walker)
Aedeagus with the ventral beak longer, Figs. 1*C*, 2*C*; apical margin of ninth segment forming only a minute membranous projection between the bases of the claspers, Figs. 1*A*, 2*A*..... 9B

9B. Ventral aspect of claspers with the apical portion narrow and almost finger-like, Fig. 1*A*; beak of aedeagus sometimes slightly recurved at tip, Fig. 1*C*..... ..... *nocturna* Ross
Ventral aspect of claspers with apical portion beyond the central constriction expanded and forming a flat wide area, Fig. 2*A*; ventral beak of aedeagus not at all reflexed, Fig. 2*C*..... ..... *ditissa* Ross

The females of both new species will key in Ross (1944, p. 239-240) to the species *O. inconspicua,* in the first alternative of couplet 16. *O. inconspicua* and the two new species may be separated by the following additional couplets:

1. Lateral-ventral portions of ninth segment wide and bandlike, terminating ventrally in a long flange (Ross 1944, Fig. 831)..... ..... *inconspicua* (Walker)
Lateral-ventral portions of ninth segment narrowed to thin straps that connect with the base of the subgenital plates, Figs. 1*D*, 2*D* 2

2. Ventral strap of ninth segment having a sinuate ridge (*r*) from base of subgenital plate and proceeding laterally across the base of the segment; anterior to this ridge is a concavity, Fig. 2*D*.... ..... *ditissa* Ross
Ventral strap of ninth segment having a fairly straight sclerotized thickening (*t*) proceeding from the base of the subgenital plate toward the lateral margin, Fig. 1*D* ..... *nocturna* Ross

Acknowledgment

This investigation was supported by a research grant from the National Science Foundation.

I wish to acknowledge the very able assistance of Dr. J. M. Kingsolver, formerly with the Illinois Natural History Survey, in making some of the preliminary drawings for this paper and for his help in sorting out much of the material on which this paper is based.

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Manuscript received July 1, 1965.

ORIGIN OF MAN AND CULTURE

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ABSTRACT.—Culture (systematic regulation of behavior) originated when mankind's immediate subhuman ancestors sanctioned or tacitly recognized as right and proper a certain set of existing natural habits.

Mankind is separated from other anthropoid species by culture, the faculty of regulating human behavior by rules. So far as known, no other primate (or other animal) species has ever achieved this. If it can be ascertained which of the successive ancestral groups first established culture, the generalized structure of its representatives will be the physical type of the human species. On this premise, man's ancestors before crossing the threshold of culture were simian; thereafter human. Since species differ in important physical structures, and human behavior is vastly more varied and complex than that of any other primate group, the foregoing statement is clearly too categorical. Such important quantitative and qualitative differences must have been long in process before culture emerged. As has been shown elsewhere, the simplest possible human society is the hunting tribe (Deuel, 1966). A species with the usual primate habits could not, in reason, be credited with changing overnight to a human society with so complex a sociocultural system as even the simplest hunting tribe exhibits. There must have been a long transitional period during which these primates adopted those habits without which they would have been unable to initiate cultures.

The wild primate species from which mankind descended, their mechanical abilities and associational habits, cannot be observed. Nor does the study of living great ape species yield more than hints to prehuman behavior since none represent a group directly in the line of human descent. However, earlier subhuman primate ancestors of man were herbivorous and presumably lived in a condition similar to that of presently existing apes. For this reason recent studies of these wild species throw a helpful light on the habits and associations of the subhominid species before it began to diverge in the direction of culture and man.

Zuckerman's observations of a captive colony of Hamadryad baboons revealed an association (''harem'') normally composed of a chief male (''overlord''), his female associate or associates, their young and a casual hanger-on (''bachelor'') or two (1932, pp. 225-6). All baboons in the wild apparently live at times ''in family parties, but more usually in large hordes'' (Ibid p. 194).

The composition of the chimpanzee groups in one natural area at least is variable as to sex and age. Moreover, members move freely from one group to another (Goodall 1963, p. 282).

The mountain gorilla on the other hand lives in relatively stable groups of fifteen to twenty individuals. These associations, though smaller than primitive hunting bands, are sufficiently large to constitute a number of distinct breeding pairs or "polygynous" sets. Whether or not such relationships or group sexual promiscuity exists is unclear and very possibly impossible to discern (Schaller 1963, pp. 237-8, 244).

It seems not unreasonable to assume, that among the various forms of primate associations, that mankind's subhuman plant-eating forebears lived into "natural family" groups resembling the Hamadryad "harem" or that similar subunits developed into a gorilla-like horde. The hypothesis that the family was foreshadowed in early subhuman associations is strongly supported by the fact that not only is the family the ever present and most enduring social unit but it is basic in the social organization and control of all societies (See White 1949, p. 315).

Captive great apes, especially the chimpanzee, have been shown capable of using crude tools spontaneously under the challenge of hunger, of learning through experience, and of being taught within limits (Köhler 1951, pp. 31-6, 125-8, Hayes and Hayes 1955, pp. 110-123). Recently Goodall has reported seeing chimpanzees use natural objects as tools, modify material (i.e. make a tool) from time to time for a specific purpose and sometimes carry it from one place to another (1963 pp. 307-8).

Judging from the cultural behavior in the simplest societies and their counterparts among living species of anthropoids, some of the habits of mankind's subhuman ancestors can be reconstructed. As White has noted in social or biological evolution the new almost invariably grows out of or is based upon the old (1949 p. 315). In brief, man's early primate ancestors were probably organized into relatively permanent "natural family" groupings, each stabilized by the mutual psychological needs of its members and the dominance of its chief male. Neighboring units gathered more or less frequently into a loose aggregate of "families." Individuals had the capacity to use sticks and stones as tools but probably exercised it rarely.

The family-like group, the friendly intergroup aggregations, the use of fire, a diet predominantly meat sustained by hunting and supplemented by collecting, the division of labor on a sex (and age) basis, cooperative experience within the group and during intergroup gatherings, technically controlled shaping of specialized tools and weapons, increase in skills, intergroup fighting and revenge, using weapons, a flexible speech structure, training of young within the group, and tradition existed and had to exist before these prehuman primates could assume the numerous and exacting obligations of a culture.

Although to outward appearance the anthropoid habits enumerated are identical with customs of primitive hunting tribes, they lack one

ingredient essential to culture. In human society, the customs or rules that regulate human behavior include an implicit agreement or acceptance by an overwhelming majority of the people that the regulations are right and proper and must be obeyed (Radcliffe-Brown 1957, pp. 56-7, Malinowski 1944, p. 43). This conviction, held in concert, so to speak, by the people of a society, constitute sanction.

Primitive people receive their customs together with the sanctions from their elders while growing up. How did the sanction that exists in primitive cultures first originate? Today laws are legislated into being and are usually accepted as binding. In what manner did the original customs appear and how were they sanctioned?

Here again there is no direct evidence. However, recent practice in England and in the United States perhaps throws some light on the subject. There is, or was until recently, a principle of custom-forming by which, under certain conditions, long-established habit became recognized as law. "Proof of unbroken possession or use of any right" from "time immemorial" ["formerly an indefinite time beyond 'legal memory' so-called"] made it unnecessary to establish an original grant," [that is, made future possession secure as if an original grant had been made]. (Webster's New International Dictionary, 1950 Edition under "time immemorial").

The example cited is one of a number of special cases of a more general cultural principle, that includes cohabitation, vested rights, and easements. In modern western societies (nations), regulations or laws governing human behavior are enacted by legally constituted law-making bodies though they are eventually subject to rejection or sanction by the people. In primitive societies, no individual or group could promulgate laws or change established custom. The example just cited is probably a vestige of an earlier common procedure by which long-continued habits of a people became binding customs.

The reasoning from this point is that important individual and associational habits of the primate forebears of man were concerned primarily with behavior involving the satisfaction of basic needs. Prior to sanction, each habit was widespread in the primitive association. Since the habit had persisted harmoniously for an indefinitely long period, each was eventually accepted and recognized as standard for behavior in like situations. (Presumably the newly created customs were of benefit to the society in that they satisfied the basic needs of the individual in association with his fellows.) This recognition was not an aggregate of consciously weighed and reasoned alternatives; it was a tacitly recognized fact in the minds and behavior of those in the group, a concert of conviction arising from long continued conditioning by the harmonious operation of the habit. Stated as a general conclusion, the important habits that had developed and been followed continously in prehuman primate associations for years beyond the memory of anyone living, produced a conviction that they were right and proper and had to be

obeyed. In more technical terms, they were sanctioned. The answer of the primitive tribesman "We do thus and so because our forefathers did it this way" denoted the seal of sanction on a custom. The young became accustomed to acting like their parents in accordance to existing forms of behavior and were thus conditioned to accept the sanction. (If customs originated in the foregoing manner the ways of life of a primitive tribe included habitual behavior as well as that regulated by custom.)

If the sanction of previously existing habits resulted in culture and elevated a group of primates to the status of mankind, it still remains to ascertain at what point it happened. Radcliffe-Brown has pointed out the differences between the recognition of economic and social rules. The economic custom is conditionally accepted, the social is mandatory. If you wish to make a good bow and arrows you must follow certain technological rules; if you don't, you fail. On the other hand the social rule that a father should not marry a close relation, for example a daughter, must be obeyed. There is no choice (Radcliffe-Brown 1957, pp. 98-99). *Compulsive regulation* in the primitive economic field (where it occurs) is social (e.g. rules of private property ownership, conveyance and inheritance) and seems to exist as a means of guaranteeing the individual's "natural rights." In advanced cultures, social control in economic matters is much enlarged, (e.g. working hours and conditions, right-to-work laws, and their nullification, minimum wage, etc.).

If the condition achieved by newly created man as described above be considered as society and the rules to which he had subjected himself as culture, it is possible to define these realities in general terms: *A culture* is a social directive system that sanctions an autonomous society with its constituent units and institutions, prescribes the manner in which it operates, provides the means to maintain and perpetuate itself and lays down the rules to regulate the behavior of the individual to these ends.

To determine which hominoid type was responsible for the crystallization of the habit system into cultures, we must turn to archaeology. The association of hominoid skeletal remains with cultural evidence found at a crucial site will solve the problem. The employment of ecological devices must, however, be used with caution since artifacts made by prehuman primates are not directly distinguishable from the simplest human kind, or in other words the point at which human culture originated cannot be determined directly by the inspection of artifacts produced by the successive representatives of the hominid line. Unfortunately neither social customs nor sanction leave objective remains. Nevertheless, archaeology with due regard to its limitations, can narrow the locus if not actually determine the position of the point sought, by providing the objects on which to base the necessary inferences.

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Manuscript received June 19, 1965.

THE MINIMAL SOCIETY

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ABSTRACT.—The fundamental units of a normal (integrated) society are the tribe (or nation) and the family.

The thesis proposed here is that each normal society, large or small, primitive or highly advanced, ancient or modern, consists of a larger comprehensive unit and a number of constituent families. There are usually one or more additional units but those noted are essential to a human society.

If, as has been suggested elsewhere, the original customs of the first societies were habits already practiced by the prehuman primate species, these habits differed from the customs in one important respect. The latter in addition to being habitual were sanctioned, that is, they were recognized as a criterion of proper behavior. Thus the "natural family" became the human family, headed by the father. The habitual gathering of neighboring families became the independent unit of culture; the family, the inviolable social unit (Deuel, 1966, p. 17).

While anthropologists generally agree that the family is a universal social unit, they do not always recognize the essential role played by the tribe among hunting peoples. The band of hunting peoples is often looked upon as an independent society and the tribe as of no real significance in the culture. "Each such [Andaman] community which will be spoken of here as a 'local group', was independent and autonomous, leading its own life and *regulating its own affairs.*" (Radcliffe-Brown 1933, p. 22. Deuel's italics).

An American anthropologist concluded from his field work some years ago that primitive peoples in sparsely settled areas were organized into autonomous land-owning patrilineal bands. Composite bands (consisting of unrelated families) were similarly ordered.

He further concluded that a free society could not be less than a family. While, at times, a family might be seasonally an independent unit, it could not, on account of commonly occurring social and economic conditions, exist generally except as a part of a group of families or a band (Steward 1936, pp. 332, 338, 343; 1955 pp. 122-150).

As a result of recent research, Dr. Steward now holds that the family, though not necessarily a land-owning group, may have been the minimal society (Personal communication).

The reasons for concluding that these territorially-fixed migratory bands are true autonomous societies

are easy to discover. The landowning and defensive powers which are attributes of the modern Western state lend color to the claim of the local group to sovereignty. Local groups forgather with one another. At times they quarrel and fight with weapons. The tribe as a unit has no dealings with other tribes nor does it wage war against them. It has no power to intervene in the operation of the local group even were internal disorder to occur. At tribal gatherings, the elders (influential men of the various bands) have no policing power to restrain those who would disturb the peace between groups; they are sanctioned merely to use their sagacity, prestige and persuasive talents to induce groups and individuals to obey custom. Though the elders in such endeavors, supported by public opinion, are almost invariably successful, this is not, to the Western mind, government.

Although the family seems thus to stand out in bold relief as the essential social unit of primitive (hunting) peoples, it is the tribe that ethnologists naturally seek first to identify and isolate for study. "The social anthropologist does this fairly simply. . . . He generally takes the abstractions made by the savages themselves. I go into a savage country and say . . . 'what language do you talk?' They give me the name of their language, 'We are the Kariera people:' They have given themselves a name. Then I ask, 'Do these people over the river speak Kariera also?' 'Yes.' 'Are those people over the hump Kariera?' 'No.' They will offer details, and they will mark off for you a definite territory, and people who talk the same language, and say those are Kariera. On the whole, language usually constitutes the line of demarcation. There is a single region which can be described as Kariera by the fact that Kariera is spoken there. There are also certain bodies of common usages which again you can describe as characteristics of these people. Therefore I can get a convenient unit which is of a people territorially delimited, speaking a common language, having common usages, and define this as my unit of study." (Radcliffe-Brown 1957, p. 61-2).

"An ethnographic survey of the world demonstrates that on every continent there are well-defined boundaries which separate, one from the other, units or cultural entities which we anthropologists call tribes. In this sense the unity of such a geographically defined group consists in the homogeneity of culture. Within the boundaries of the tribe the writ of the same culture runs from end to end. The tribesmen all speak the same language, hence accept the same tradition in mythology and customary law, in economic values and in moral principles. With this there runs parallel a similarity of techniques and implements, of tastes and consumers' goods. They fight, hunt, fish, and till the soil with the same type of implements and weapons, and they intermarry according to the same tribal law of matrimony and descent. . . . The tribe as a cultural unit probably existed long before the political tribe became organized on the principle of force." (Malinowski 1944, pp. 60, 61).

There are, however, more cogent cultural ("legal") reasons for main-

taining that the tribe is always present among primitive peoples as an important functioning unit. This is the implication of institutions widely present or universal among them and tribally limited as to jurisdiction—blood vengeance, marriage, political and kinship systems of social control, initiation, land ownership, and cultural training in the family.

Blood vengeance, unlike personal revenge, is a right of the family (local group) to protect itself and defend the natural rights of its members, a custom recognized and accepted throughout the tribe. The family (local group) of the person committing the crime is responsible for the act. The injured family is sanctioned to mete out punishment to the offending group. A feud, should it arise as a result of retribution, is not a custom; it is a violation of cultural regulation. The fear of feuds, common among hunting peoples, is itself a deterrent to this breach of custom.

Among many tribes, additional mechanisms exist to avoid feuding. In some instances, permission is sought of relatives of a man guilty of a crime, before he is executed. Leaders of a local group may at times arrange for another group to kill a non-conformist or very quarrelsome member whose behavior endangers friendly relationships with its neighbors.

The custom of blood vengeance is tribal not familial. The avenging family or local group cannot direct the custom of blood vengeance in its entirety since it has no restraining social authority over the opposing unit. A feud is usually avoided through public opinion, the general tribal feeling that the avenging act was right and just and the unit "punished" should abide by it. The restraint is imposed by the consensus against continuance of the quarrel felt throughout the tribe by virtue of a common cultural training during youth. This carries with it the guarantee that neither unit involved will suffer a loss of social standing.

Marriage among primitive hunting peoples is a contract between two families to establish a third. The contract is bound by the exchange of gifts and/or services which begin in advance and may extend over a considerable period after the marriage proper takes place. Normally these conditions are fulfilled, not because either family can enforce the contract or its provisions, but because the consensus of the whole tribe is that the custom is right and should be carried out in the prescribed manner (Note: As in all normal cultural behavior, there is a desire on the part of those primarily involved to cooperate. This cooperation stems directly from the recognition and acceptance of the rightness of the customs by those participating.)

Initiation ceremonies are rites which mark the arrival of the young human male at manhood. Though the ritual observance may be within the local group, it is the customary manner of admitting youth to full membership in the society. The rites are thus tribal, not local, in purpose, as is shown by the acceptance of the successful candidate at tribal gatherings as one of the initiated men, as a man eligible for marriage and for a man's duties generally.

The principle of land ownership by the family (local group) could not be effective except by general acceptance by the tribal units. Cultural training of youth in the family is not a mere family or group matter, it concerns the tribal culture, the customs of all the families.

A final objection to the band as an independent society lies in the nature and source of its authority. Political authority or societal control resides (even in the hunting tribe) in the total society or aggregate of families and emanates downward to the constituent social units. Except among primitive hunting peoples, political authority is coterminous with police powers, the sanction to compel cultural conformity by force.

The authority of the local group, on the other hand, is based on the kinship system. The kinship system of social control is built on terms expressing degrees of relationship and the associated mutual rights and duties between members of the simple family, extended to more distant lineal and collateral relatives, to those related by marriage and even to unrelated families residing locally. The authority flows upward from the simple family to more inclusive kinship bodies to the local group or band. The latter consequently can wield no greater customary powers than those exercised by the family. Police power (blood vengeance for crimes) is an inherent natural right reserved to the family (local group). The phrase "family (local group)" expresses this inseparable relationship in this matter of kinship structure with associated duties and unit powers. Thus the local group can *exercise* the rights of blood vengeance, land ownership, protection of individual's natural rights, etc., but cannot sanction these rights, the family or itself. The aggregate of families can and does sanction the family (local group) as a social unit and its natural rights including the right to defend itself by force. The family, for its part, trains the young to conform to the culture and support the tribal institutions. In this manner the two social units complement and maintain each other.

Since a "natural family" (prehuman primate associational grouping) could not sanction itself, its social condition could only be realized by an aggregate of families, each of which recognized and accepted as right and proper, the same traditional set of customs. Consequently human families can be found only as parts of a larger social body, the tribe or nation, which is regulated by culture. (Note: A family or a local group might, of course, exist for a time as a "free" agent due to historical accident such as the destruction or dispersal of a tribe but from a "social" standpoint it is then in the condition of a "natural family" and its further activities purely of historical concern.)

Contrary to the above line of reasoning, some anthropologists have proposed that man is the true unit of society. "In a social system, the entities are individual human beings, in certain relations, which are differentiated from and isolated from all other relations in the universe. The individuals exist as units, but also, considered through time, are each characterized by a set of related acts of behavior which themselves

constitute a system.'' (Radcliffe-Brown 1957, p. 43). Without man there could be no culture and no society and therefore (or so the reasoning goes) man must be the unit of society.

A careful review of the earlier argument will reveal that sanction, the vivifying spirit of culture, is not an individual matter nor an aggregate of conscious acceptances but a concert of conviction of the people as a whole (Deuel 1964). While individuals are essential to the operation of culture and society, they do not determine the customs, the social procedures, nor structures; rather they play roles analogous to the living cells that compose and operate the human body, but neither determine the mechanisms nor direct the processes.

Summary

Historically, the family originated in a habitual prehuman primate breeding and rearing association or ''natural family.'' The tribe was probably likewise the outgrowth of a not unusual primate tendency for ''natural families'' to assemble in a larger body for companionship and/or for common undertakings like the baboon raids on South African orchards (Zuckerman, 1932, pp. 194-6, 198). This aggregate of neighboring scattered groups was casual and its earliest composition may have been variable.

The human family was created through sanctioning by the aggregate of neighboring cooperative ''natural families.'' The family organization, the means to perpetuate it as a social unit, and its rights or the habits by which it maintained itself were sanctioned at the same time. Sanction of the family and its natural habits was effected only by implicit recognition and conviction of their rightness by the aggregate of families, the tribe. Sanction, however, is not a momentary but a continuing conviction.

Consequently the tribe (or society) is essential to insure the perpetuation of the family and the sanction of its natural rights or the culture. The family by training the young from infancy preserves and passes the tribal culture on to succeeding generations. Thus the tribe and family are the mutually supporting social units essential to the establishment and maintenance of a society.

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Manuscript received June 19, 1965.

BLUFF PRAIRIE VEGETATION AND SOIL TEXTURE

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ABSTRACT.—As a further analysis of soil-vegetation relationships in hill prairies, soil textural percentages, vegetational data, and other ecological features were obtained from five of these prairies in Jersey County, Illinois. The results showed a wide soil texture variation with corresponding variations in floristic composition, but indicate that other ecological factors modify this correlation considerably.

Small, undisturbed prairies dominate many of the exposed south and southwest facing bluff slopes of the Mississippi, Illinois, Missouri and other sizeable rivers of the midwest. These grasslands, which have been referred to in the past as "hill" prairies (Evers, 1955, p. 367), are best termed "bluff" prairies inasmuch as they are normally situated on high bluffs overlooking these rivers. Seldom exceeding one acre in size, and often much smaller, they are xeric remnants of the extensive prairies that once covered much of this area. While forest predominates immediately over the crest of these bluffs, usually on northerly facing slopes, the high temperatures and strong winds on these steep southerly-facing slopes help create dry, rigorous climatic conditions favoring prairie vegetation.

The soil of these prairies is derived from the loess cap atop the limestone bluffs. This material is generally considered to be a wind deposit from the floodplains of the Pleistocene Rivers (Smith, 1942), and is, in many places, forty feet thick, but at the stone-loess interface the soil slumps over the rock and is very shallow. Prairies extend over onto these shallow soils which often have depths under two feet.

Ecological investigation of bluff prairies is not extensive. Braun (1950, p. 330) describes their widespread occurrence along the bluffs of the Mississippi River in Wisconsin, Minnesota, Iowa and Illinois. Evers (1955) made an extensive floristic sampling of these prairies throughout Illinois, while Kilburn and Ford (1963) and Kilburn and Warren (1963) have analyzed their vegetational features and soil texture of prairies in Jersey County, near Alton, Illinois. These studies have concluded that the soils of the bluff prairies are sandy, and are dominated by little bluestem (*Andropogon scoparius*).

Wider investigation of local bluff prairies and their soils revealed that they possessed far more vegetational and soil-textural variation than had been described. It was to assess the effect of soil textural variation on vegetational structure and composition that this study was undertaken. The results strongly suggest a tex-

ture-vegetation correlation, but indicate that other ecological factors including slope, exposure and past history, modify this correlation considerably.

Methods of Study

Prairies located some four miles along the Mississippi River bluffs of the Principia College Campus, T6N R11W, Jersey County, Illinois, were first surveyed and a general description of the vegetation obtained. Soil samples were taken and analyzed in the field. Five prairies that showed apparent differences in soil texture and vegetation were chosen. Vegetation information was recorded from ten to twelve one-meter quadrats regularly spaced in the upper, middle, and lower hill slope regions, and frequency and coverage data (Oosting, 1956, pp. 60, 62) were taken from them. Nomenclature follows Fernald (1950).

Whenever possible, a soil sample was taken at the one foot, two foot, and three foot levels at each of the ten quadrats, although at three prairies the depth of the soil was less than three feet and samples were only taken at the one and two foot levels. The Bouyoucos Method was used in analyzing 80 soil samples from the five prairies.

Results

The soil textural analysis (Table 1) shows a wide variation in the texture of the soils at the various prairies. Two prairies, Black Widow and Grassy Hollow, are quite sandy with average sand percent of 79.7 and 70.3 respectively; one, Prairie Bean, has a more even distribution of sand, silt, and clay, and thus a loamy texture, while the remaining two show high silt percentages of 69.1 and 69.7 per cent.

The vegetational analysis revealed a total of 46 plant species from 11 different families in the five prairies. Both the grasses and composites each had slightly over 25 per cent of the number of species. The legumes had 17.4 per cent of the number of species, and other families were not noticeably represented.

Table 2 shows that the grasses have much higher coverage values than the forbs. Although some forbs had frequencies up to 90 per cent (*Silphium laciniatum* and *Liatris cylindracea*), their average coverage never exceeded 4.5 per cent. In addition, the forb composition varies considerably from one prairie to the next, and no correlations with soils were evident. On the other hand, little bluestem (*Andropogon scoparius*) occurs in all five prairies and dominates (has the highest coverage value) in three. Indian grass (*Sorghastrum nutans*) and big bluestem (*A. gerardi*) occur in three prairies, dominating in two. Side oats grama (*Bouteloua curtipendula*), while never dominating, is present in all five prairies with average frequencies ranging from 30 per cent to 100 per cent.

Other important ecological variations were noted: slope, the vertical drop per 100 feet; exposure, the direction the bluffs are facing; and soil depth. The slope averages (Table 1) varied from 14.2 per cent to 51.3 per cent; the exposures, from 28° west of south to 10° west of south, and the soil depth, from one foot to greater than three feet. The small number of prairies sampled did not permit assessing the importance of each factor, although their possible influence is discussed later.

Discussion

The steep, sandy slopes allowing a rapid loss of water, both through percolation and rapid runoff, apparently favor the more xeric grasses, *Andropogon scoparius* and *Bouteloua curtipendula*. The presence index of the dominant grasses (Table 3), a figure based upon 10 per cent of the product of the species average

Table 1.—Soil Texture Percents and percent Slope Measurement in Hill Prairies. Figures for each prairie based on an average of sixteen soil samples and on an average of six slope measurements.

Prairie	Sand	Silt	Clay	Av. Slope
Black Widow	79.7	16.6	4.5	51
Grassy Hollow	70.3	22.7	7.2	44
Bean	31.8	47.6	20.1	40
Snake Den	26.4	69.1	4.4	29
Picnic	22.8	69.7	7.4	19

TABLE 2.—Vegetational Coverage and Frequency Percentages for Predominant Hill Prairie Plants. Figures based on ten to twelve m^2 quadrats in each prairie.

Plant	Black Widow		Grassy Hollow		Prairie Bean		Snake Den		Picnic	
	Cov.	Fr.	Cov.	Fr.	Cov.	Fr.	Cov.	Fr.	Cov.	Fr.
Andropogon scoparius	37.3	100	32.0	100	34.0	100	4.5	30	13.5	60
Bouteloua curtipendula	8.6	72	12.0	83	7.5	80	7.0	30	1.8	30
Sorghastrum nutans	0.0	0	0.0	0	5.0	20	20.6	70	30.0	30
Andropogon gerardi	0.0	0	0.0	0	4.5	20	0.0	0	16.0	90
Sporobolus asper	10.0	64	1.3	25	2.0	10	8.5	20	6.6	40
Petalostemum purpureum	0.5	12	0.2	16	1.4	70	0.3	40	0.1	10
Solidago radula	0.6	27	0.3	33	0.2	20	1.8	40	0.0	0
Solidago speciosa	0.0	0	0.0	0	0.0	0	1.1	20	0.1	10
Echinacea pallida	0.0	0	1.0	16	1.3	70	0.0	0	0.1	10
Silphium laciniatum	0.0	0	0.0	0	4.5	90	3.1	40	0.0	0
Lespedeza virginica	0.0	0	0.4	25	1.0	40	0.1	10	0.0	0
Liatris cylindracea	0.0	0	0.4	16	1.7	90	0.0	0	0.0	0

TABLE 3.—Presence Index of Dominant Grasses. Figures based on 10% of the species average frequency times average coverage.

Texture Class	Black Widow	Grassy Hollow	Prairie Bean	Snake Den	Picnic
	Loamy Sand	Sand Loam	Loam	Silt Loam	Silt Loam
Plant					
Andropogon scoparius	373.0	320.0	340.0	13.5	81.0
Bouteloua curtipendula	61.9	99.6	60.1	21.0	5.4
Tall Grasses (A. gerardi & Sorghastrum nutans)	0.0	0.0	19.0	144.2	234.0

frequency by its average density, shows that the loamy or silt-loam soils support mesic grasses, *A. gerardi* and *S. nutans,* as well as the xeric ones. In the two prairies with the greatest silt percentages, the mesic grasses dominated. In the loam prairie with an average of 20 per cent clay, *A. gerardi* and *S. nutans* were present although *A. scoparius* dominated.

Results from only six soil samples from Pere Marquette State Park, situated on the Illinois River 12 miles west of the campus prairies, are not included in Table 1 for several reasons. The samples averaged 77 per cent silt with only 15 per cent sand. Unlike the other silt-loam prairies, this one is dominated by *Andropogon scoparius* and not by *A. gerardi* and *Sorghastrum nutans,* although the latter grasses do occur. These aberrant results do not, we feel, detract from the texture-vegetation correlations discussed above, for the Pere Marquette prairie is not only far away, but its topography is more gentle, and it is not situated above limestone bluffs. It has undoubtedly had a far different past history of grazing and fire, and consequently, comparison with Principia prairies is invalid.

Although the soil texture within each of the five prairies is fairly homogeneous, there appear to be gradations in vegetation within these prairies. *Bouteloua curtipendula* and *Sporobolus asper* were commonly more abundant at the lower edges of the prairies where the slope is often greater and the soil depth more shallow. More study is needed to assess this correlation.

The correlation with soil texture and vegetation, although suggestive, is hardly conclusive on the basis of these few prairies. Although an important factor, its influence may be modified or overriden by several other ecological factors. One, which is being investigated, is the soil mineral content, especially the calcium content. Another is past history and land use. Still other factors, which would have strong influences on available moisture and which differed among the prairies, are slope and exposure. The degree of slope directly influences water infiltration and runoff and thus directly affects available moisture. The direction the prairie faces and its exposure, in part, control the temperature, which directly influences plant transpiration and soil evaporation. Assessment of each of these factors remains a future goal.

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Manuscript received June 16, 1965.

THE ILLINOIS TAXA OF *PASPALUM*

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ABSTRACT.—The grass genus *Paspalum* is composed of seven taxa in Illinois. This paper presents detailed descriptions and discussions of the taxa. A key for identification of Illinois taxa is provided, as well as an annotated list of specimens examined.

Paspalum, a genus in the tribe Paniceae of the family Gramineae, is a group in which several species show considerable morphological variation. Series of intermediate forms exist between several of these species, and descriptions of some species appear to have been based on specimens which exhibited extremes of variation for such species. This study is intended to define species of *Paspalum,* provide a key for identifying these species, give synonymy, and show distribution of the taxa in Illinois. The synonymy given is essentially that of Chase (1929).

Herbaria of the Illinois State Museum (ISM), Illinois Natural History Survey (ILLS), University of Illinois (ILL), Missouri Botanical Garden (MO), Chicago Museum of Natural History (F), and Southern Illinois University (SIU) made their collections available for this study. This research was supported in part by research grant ♯CC 00047 from the Communicable Disease Center, U. S. Public Health Service.

HISTORY OF THE GENUS

Paspalum was described by Linnaeus in 1759. Several agrostologists have studied *Paspalum,* climaxed by the monographic work of Chase in 1929. In her study, Chase recognized 140 North American species, 6 of which she reported from Illinois. When Chase revised Hitchcock (1950) she made several minor changes in synonymy.

Among the workers in Illinois (Jones, 1950; Mohlenbrock and Voigt, 1959) and those who have included Illinois in their floristic treatments (Gleason, 1952; Fernald, 1950; Hitchcock, 1950) there is little agreement concerning the genus.

Various authors have included species of *Digitaria, Axonopus, Cabera, Eriochloa, Capriola,* and *Anastrophus* in *Paspalum* (Chase, 1929).

GEOGRAPHICAL AND ECOLOGICAL CONSIDERATIONS

Paspalum is a genus which tends to be most abundant and diverse in the tropics, particularly of the western hemisphere. Only 40 of 140 North American species recognized by Chase (1929) occur within continental United States. Hitchcock (1950) recorded 49 species from the United States, 8 from Illinois.

In Illinois, with exception of *P. ciliatifolium, Paspalum* is restricted to the southern two-thirds of the state. Various species may be encountered in such diverse habitats as sand and hill prairies, railroad ballast, fencerows, open pastures, meadows, roadside ditches, openings in moist woods, stream borders, and shallow swamps.

Paspalum ciliatifolium is scattered throughout Illinois, but its distribution tends to be associated with major stream valleys of the state (Fig. 1). In these areas, it is more frequently encountered in dry situations, particularly where soils are sandy.

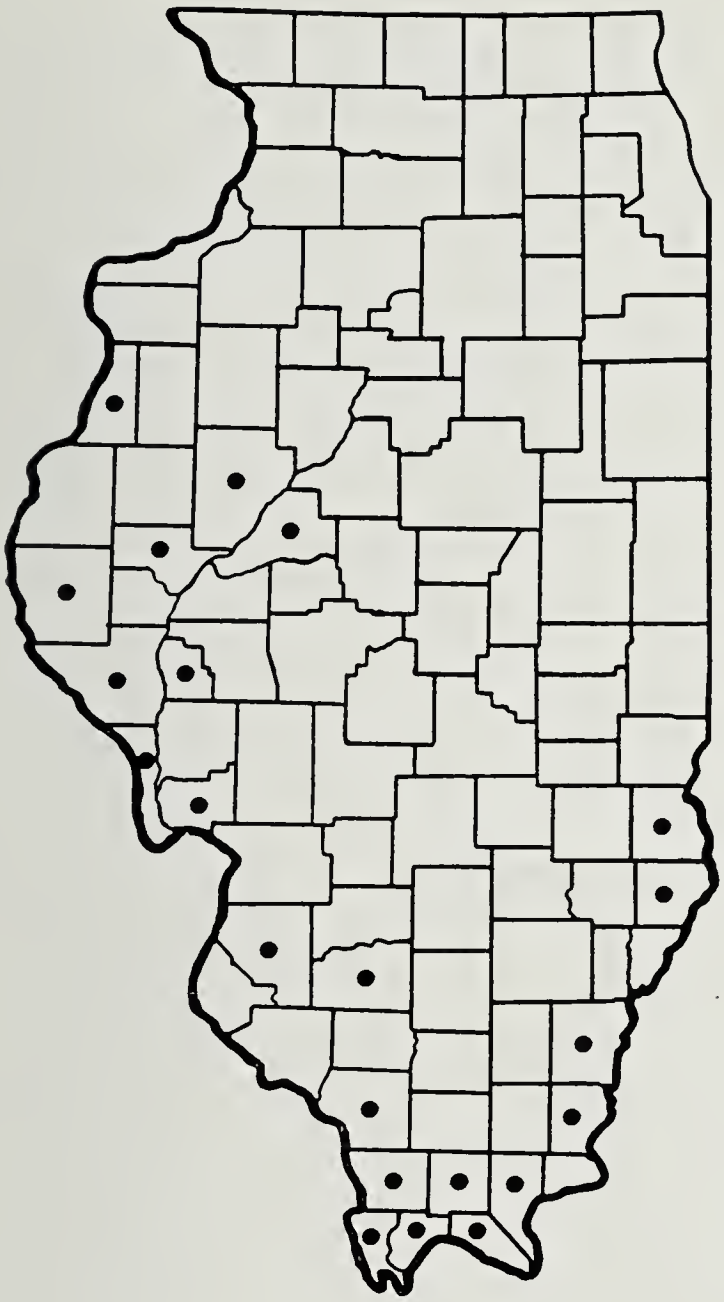
Paspalum pubiflorum var. *glabrum,* common in southern counties, also tends to be somewhat more common along major streams (Fig. 2). Although moist habitats appear to be preferred, this species is relatively tolerant of drought.

Paspalum fluitans is restricted mostly to counties bordering the Mississippi, Illinois, Ohio, and Wabash rivers (Fig. 3), appearing to be fairly common in shallow water of swamps. It appears to be restricted to such habitats.

Figure 1.—Distribution of *Paspalum ciliatifolium* in Illinois.

Figure 2.—Distribution of *Paspalum pubiflorum* var. *glabrum* in Illinois.

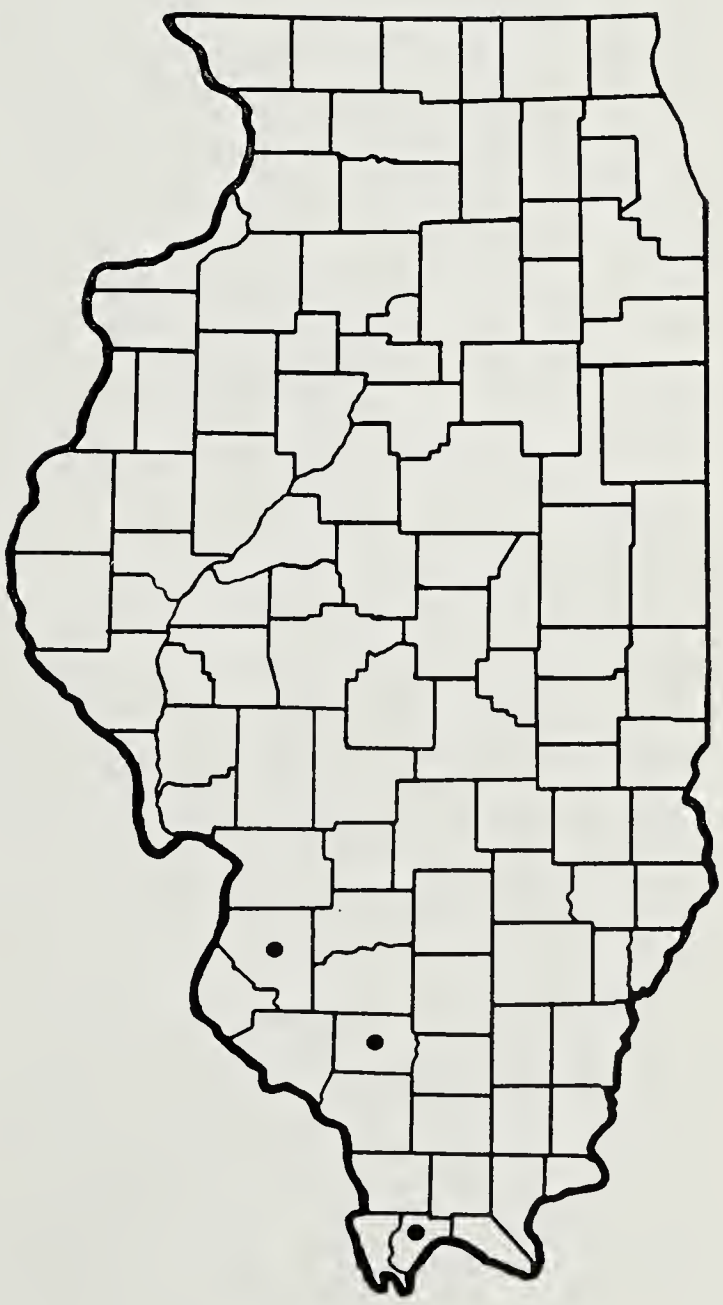
Figure 3.—Distribution of *Paspalum fluitans* in Illinois.



Paspalum floridanum has a restricted range within the southernmost fourth of Illinois (Fig. 6). It is known only from Jackson, Franklin, Perry, Washington, and Williamson counties, where it is encountered most frequently in moist habitats along highway and railroad rights-of-way.

The adventive, *P. lentiferum,* has been collected recently in Pulaski County, where it forms extensive colonies in a low roadside ditch near Karnak (Fig. 7).

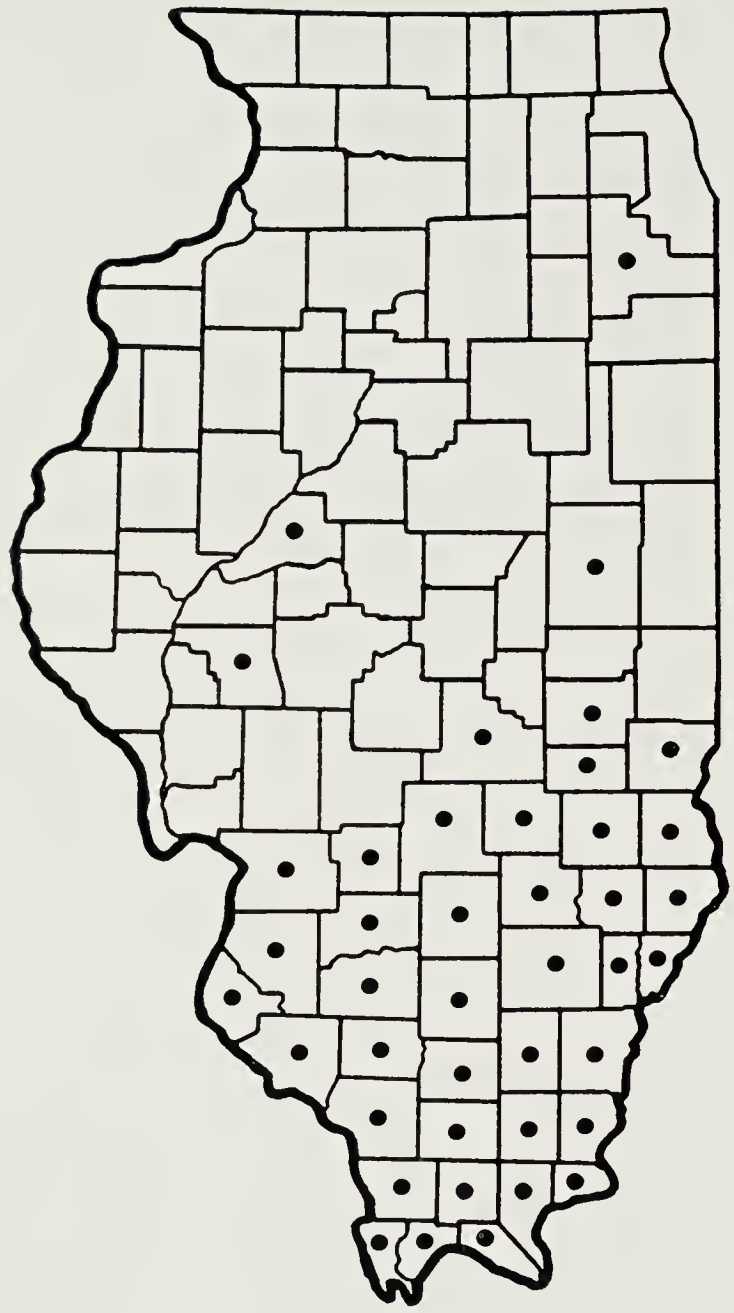
Figure 4.—Distribution of *Paspalum dissectum* in Illinois.



Paspalum dissectum is known only from three scattered southwestern counties (Fig. 4). Like *P. fluitans,* it appears to be tolerant of excessive moisture in swampy areas, but it does not appear to be restricted to habitats containing standing water.

Paspalum laeve is the most common species in the southern third of the state; there are a few scattered records from some northern counties (Fig. 5). This species is most abundant in moist soils in roadside ditches, meadows, and along stream borders.

Figure 5.—Distribuiton of *Paspalum laeve* in Illinois.



Morphology of the Genus

Annuals or perennials; inflorescence of many 1-flowered, usually plano-convex, subsessile, solitary or paired spikelets arranged along a central axis in 2 or 4 rows with the convex sides toward the rachis, forming simple spike-like racemes; racemes 1-many, digitate or racemose, terminal; first glume usually wanting; second glume similar to sterile lemma; fertile lemma and palea chartaceous-indurate, the margins of the lemma inrolled at maturity; stamens 3; styles 2; stigmas plumose.

Key to the Illinois Taxa of *Paspalum*

A. Rachis foliaceous, the margins folded over and clasping the spikelets or their bases.
   B. Racemes of each inflorescence 1-5; rachis shorter than the rows of spikelets..... .....1. *P. dissectum*
   B. Racemes of each inflorescence 5-50, usually more than 10; rachis longer than the rows of spikelets .....2. *P. fluitans*

A. Rachis firm, narrow or broad, but the margins not folded over the rows of spikelets.
   C. Rachis broad, over 1.5 mm wide; spikelets appear to be arranged in 4 rows..... ..3. *P. pubiflorum* var. *glabrum*

Figure 6.—Distribution of *Paspalum floridanum* in Illinois.

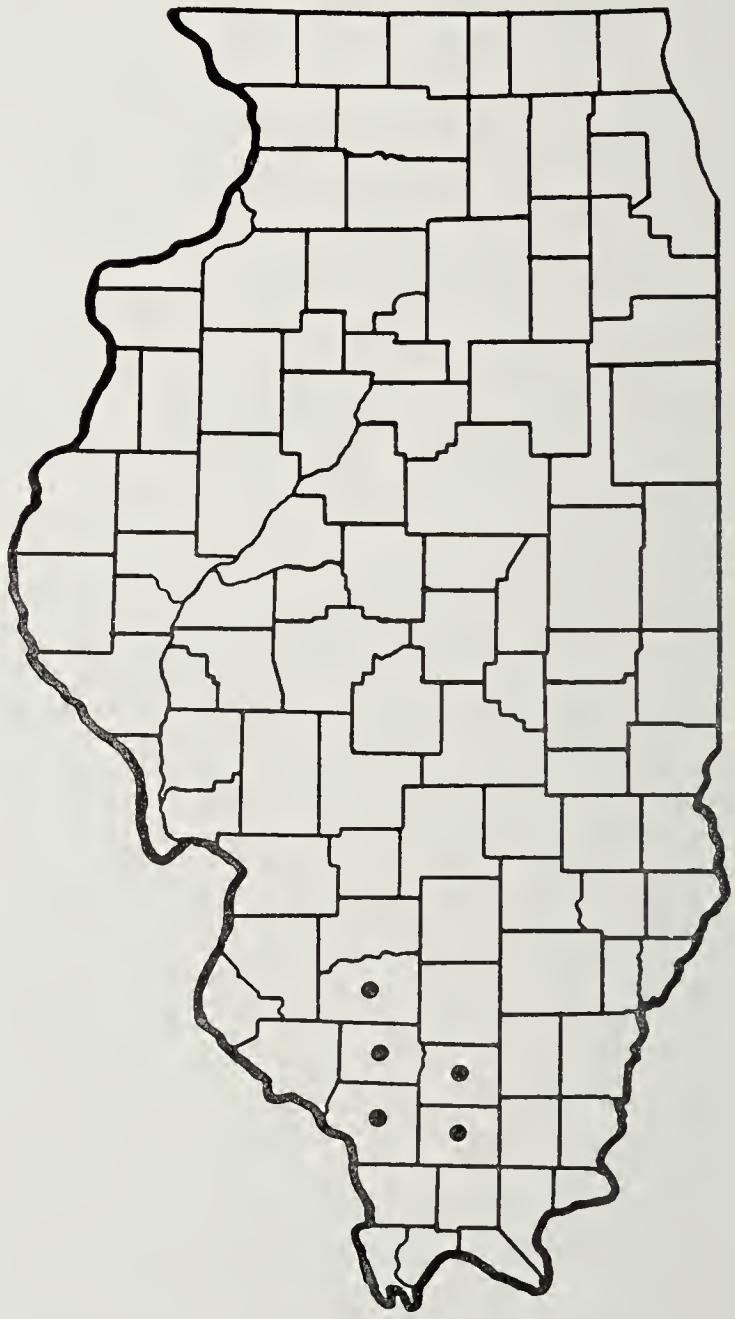
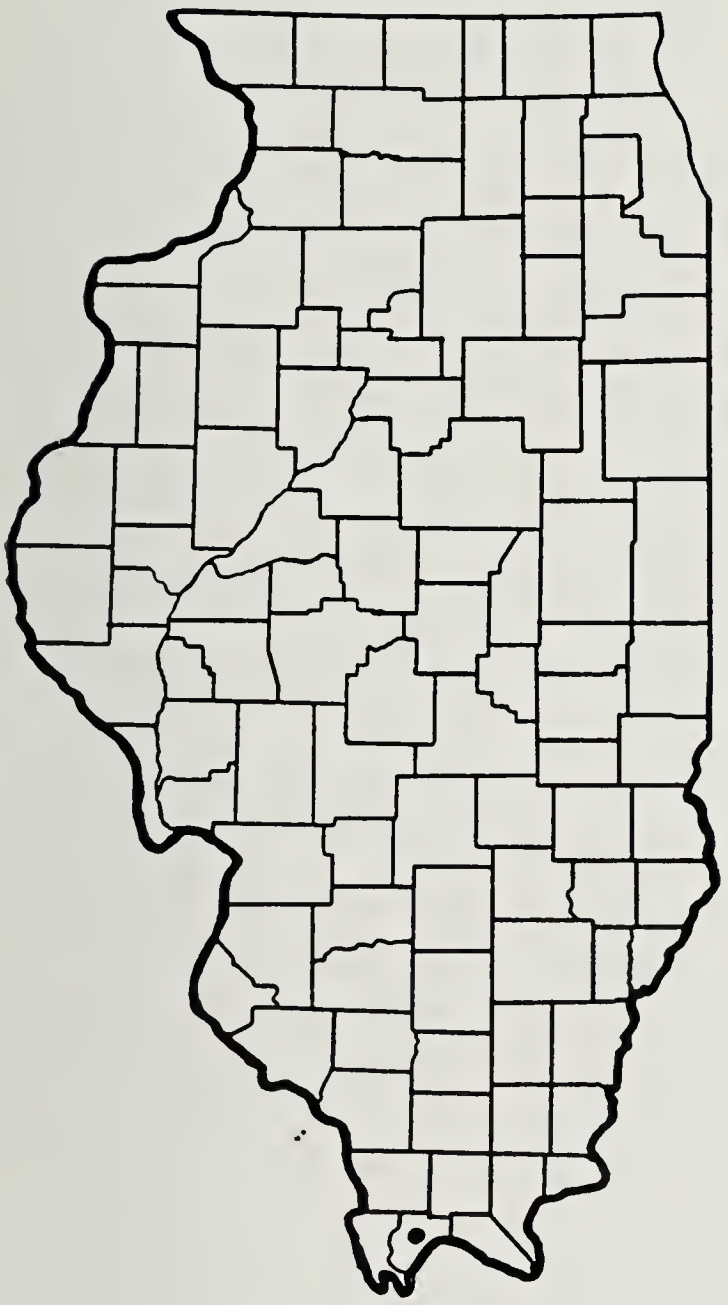


Figure 7.—Distribution of *Paspalum lentiferum* in Illinois.



C. Rachis narrow, less than 1.5 mm wide (about 1.5 mm wide in *P. lentiferum;* spikelets in 2 rows (4 rows in parts of some racemes of *P. floridanum*).
  D. Spikelets 3.6 mm long or longer; culms robust, 1-2 m tall .....4. *P. floridanum*
  D. Spikelets less than 3.2 mm long; culms slender, usually less than 1 m tall.
    E. Spikelets 2.5-3.2 (-3.4) mm long; sterile lemma 5-veined with lateral veins approximate at the margins.
      F. Leaves glabrous to sparsely pilose..... .....5. *P. laeve*
      F. Leaves pilose, becoming villous at base ....6. *P. lentiferum*
    E. Spikelets 1.2-2.4 mm long; sterile lemma 3-veined, the marginal veins obscure at maturity...7. *P. ciliatifolium*

Syetematic Treatment of the Taxa

1. *Paspalum dissectum* (L.) L. Sp. Pl. ed. 2:81. 1762.

Panicum dissectum L. Sp. Pl. 57. 1753.
Paspalum dimidiatum L. Syst. Nat. ed. 10, 2:855. 1759.
Paspalum membranaceum Walt. Fl. Carol. 75. 1788.
Paspalum vaginatum Ell. Bot. S. C. & Ga. 1:109. 1816.
Paspalum walterianum Schult. Mant. 2:166. 1824.
Paspalum tectum Steud. Syn. Pl. Glum. 1:29. 1854.
Paspalum drummondii C. Muell. in Bot. Zeit. 19:332. 1861.

Creeping, branching, glabrous, subaquatic, perennial; culms repent, 20-60 cm long, often forming mats; leaves 3-6 cm long, 4-5 mm wide; racemes 1-5, 2-3 cm long, terminal or axillary, falling entire; rachis membranous, 2-3 mm wide, narrower and shorter than the rows of spikelets but folded over and clasping them; spikelets glabrous, ovoid to obovoid, 2 mm long, 1.4 mm wide; glume and sterile lemma 3- to 5-nerved, slightly longer than the fruit.

Habitats.—Moist soil to edges of shallow swamps.

Range.—New Jersey to Missouri south to Texas and Florida.

Paspalum dissectum is distinguished easily by the terminal spikelet extending well beyond the tip of the infolded rachis.

Only 3 specimens have been collected in Illinois, none since 1893. It is uncertain whether this species still occurs within the state.

Specimens examined.—Perry: locality unknown, *Eggert s.n.* (ILL). Pulaski: Mound City, *Brendel s.n.* (ILL). St. Clair: locality unknown, *Brendel s.n.* (ILL).

2. *Paspalum fluitans* (Ell.) Kunth, Rev. Gram. 1:24. 1829.

Ceresia fluitans Ell. Bot. S. C. & Ga. 1:109. 1816.
Paspalum mucronatum Muhl. Descr. Gram. 96. 1817.
Paspalum natans LeConte, in Journ. de Phys. 91:285. 1820.
Paspalum pyramidale Nees, Agrost. Bras. 77. 1829.

Paspalum frankii Steud. Syn. Pl. Glum. 1:19. 1854.
Paspalum bistipulatum Steud. Syn. Pl. Glum. 1:29. 1854.
Cymatochloa fluitans Schlecht. in Bot. Zeit. 12:822. 1854.
Cymatochloa repens Schlecht in Bot. Zeit. 12:822. 1854.

Sprawling or repent, branching, glabrous, aquatic, annual; culms soft and spongy, 30-100 cm long; leaves 10-20 cm long, 10-15 mm wide; racemes 5-50, usually more than 10, 3-8 cm long, spreading or recurved; rachis herbaceous, 1.3-2.0 mm wide, wider and longer than the rows of spikelets but folded over and clasping them; spikelets minutely glandular pubescent, ellipsoidal, 1.3-2.0 mm long, 0.8 mm wide; glume and sterile lemma 2-nerved, the mid-nerve suppressed, slightly longer than the fruit.

Habitats.—Floating in shallow standing water. Terrestrial plants are dwarfed.

Range.—North Carolina to Kansas south to Texas and Florida.

Paspalum fluitans is distinguished readily by its numerous racemes and by its rachis infolding and clasping all of the spikelets.

Specimens examined.—Adams: Quincy, *Bellrose s. n.* (ILLS). Alexander: two miles E. of Miller City, *Buser 5401* (ILLS). Calhoun: Brussels, *Bellrose s. n.* (ILLS). Crawford: eight miles S. of Oblong, *Ahles 4993* (ILL). Fulton: Anderson Lake, *Winterringer 12245* (ISM). Gallatin: Shawneetown, *Brewer s. n.* (SIU). Henderson: Oquawka, *Patterson s. n.* (ILL). Jackson: Turkey Bayou, *Bailey & Swayne 2886* (ISM). Jersey: Pere Marquette State Park, *Fuller & Link 403* (ISM). Johnson: Belknap, *Gleason s. n.* (ILL). Lawrence: Lawrenceville, *Sivert s. n.* (ILL). Mason: locality unknown, *Rexroat 708* (ISM). Massac: two miles S of Unionville, *Evers 55615* (ILLS). Pike: N of Florence, *Evers 20266* (ILLS). Pope: Grantsburg, *Ahles 1809* (ILL). Pulaski: Olmstead, *Thieret 2476* (ILLS). St. Clair: W of Lebanon, *Evers 14258* (ILLS). Schuyler: three miles SW of Beardstown, *Rexroat 2317* (ISM). Scott: Naples, *Rexroat 4475* (ISM). Union: Wolf Lake, *Bailey & Swayne 1802* (SIU). Washington: twelve miles W of Nashville, *Winterringer 7344* (ISM). White: S of Mill Shoals, *Ahles 6638* (ILL).

3. *Paspalum pubiflorum* var. *glabrum* Vasey ex Scribn. in Bull. Tenn. Exp. Sta. 7:32. 1894.
Paspalum remotum var. *glabrum* Vasey, in Bull. Torrey Club 13:166. 1886.
Paspalum geminum Nash, in Bull. N. Y. Bot. Gard. 1:434. 1900.
Paspalum laeviglume Scribn. ex Nash, in Small, Fl. Southeast. U.S. 75. 1903.

Decumbent, rooting at the nodes, glabrous to pubescent, perennial; culms stout, geniculate, 40-200 cm tall; leaves 10-15 cm long, 6-20 mm wide, pilose on the margin; racemes 4-8, usually 5 or more, the lower frequently distant, 2-10 cm long; rachis with scarious, nearly wing-like margin, 1.2-2.0 mm wide, frequently near maximum; spikelets in pairs, glabrous, obovoid, 3.0-3.2 mm long, about 2 mm wide; glume and sterile lemma 3- to 5-veined.

Habitats.—In moist soil in ditches, along roadsides, and along streams; tolerant of drought.

Range.—Pennsylvania to Kansas south to Texas and Florida.

Paspalum pubiflorum var. *glabrum* may be distinguished easily from other Illinois species by its wide rachis and its paired spikelets which appear to be in 4 rows along the rachis. The typical variety, which does not enter Illinois, has puberulent spikelets.

Nash's *P. geminum*, used by several Illinois workers, is based upon material identical with *P. pubiflorum* var. *glabrum*.

This grass is sometimes used for forage.

Specimens examined.—Alexander: SE of Thebes, *Evers 55511* (ILLS). Clay: Flora, *Ahles 6609* (ISM). Cumberland: S of Neoga, *Evers 59303* (ILLS). Edwards: S of Brown, *Evers 55124* (ILLS). Franklin: two miles S of Sesser, *Evers 52350* (ILLS). Gallatin: SW of Ridgeway, *Evers 40737* (ILLS). Hardin: near Herod, *Winterringer 2422* (ISM). Jackson: one-half mile S of SIU campus, *Voigt 758* (SIU). Jefferson: S of Dix, *Evers 15344* (ILLS). Johnson: E of Vienna, *Bailey & Swayne 2933* (SIU). Massac: two miles SE of Mermet, *Evers 44429* (ILLS). Pope: Dixon Springs State Park, *Pierre s. n.* (ILL). Pulaski: W of Karnak, *Winterringer 11916* (ISM). Randolph: Prairie du Rocher, *Winterringer 17106* (ISM). St. Clair: Stripmine area, *Grandt s. n.* (ILL). Union: Pine Hills Swamp, *Stieglitz 9* (SIU). Wabash: S of Mt. Carmel, *Winterringer 13743* (ISM). White: two miles E of Crossville, *Winterringer 8949* (ISM). Williamson: Crab Orchard Lake, *Weik 5* (SIU).

4. *Paspalum floridanum* Michx. Fl. Bor. Amer. 1:44. 1803.

Paspalum macrospermus Flugge, Monogr. Pasp. 172. 1810.

Paspalum glabrum Bosc in Flugge, Monogr. Pasp. 172. 1810.

Paspalum laevigatum Poir, Encycl. Suppl. 4:313. 1816.

Paspalum laeve var. *floridanum* Wood, Class-book 782. 1861.

Erect, stout, glabrous, perennial; culms solitary or few, 80-200 cm tall, commonly 150-200 cm tall; leaves 12-50 cm long, 4-10 cm wide; racemes 2-6, usually 3 or 4, 4-12 cm long, suberect or ascending; rachis 1.0-1.4 mm wide, strongly flexuous; spikelets in pairs (one of pair sometimes rudimentary), glabrous, crowded, oval, 3.6-4.0 mm long, 2.8-3.1 mm wide; glume and sterile lemma firm and papery, 5-veined, scarcely covering fruit at maturity.

Habitat.—Low, moist sandy soil.

Range.—Pennsylvania to Kansas south to Oklahoma, Texas, and Florida.

Paspalum floridanum is distinguishable from other Illinois taxa by its large spikelets. It is apparently rare in the state.

Specimens examined.—Franklin: S of Benton, *Evers 55408* (ILLS). Jackson: Elkville, *Verts 351* (SIU). Perry: N of Cutler, *Thieret 2790* (ILLS). Washington: E of Nashville, *Winterringer s. n.* (ISM). Williamson: N of Marion, *Evers 27878* (ILLS).

5. *Paspalum laeve* Michx. Fl. Bor. Amer. 1:44. 1803.

Paspalum undulosum LeConte, in Journ. de Phys. 91:285. 1820.

Paspalum angustifolium LeConte, in Journ. de Phys. 91:285. 1820.

Paspalum alternans Steud. Syn. Pl. Glum. 1:26. 1854.

Paspalum tenue Darby, Bot. South. States 576. 1857.

Paspalum laeve var. *undulosum* Wood, Class-book 782. 1861.

Paspalum laeve var. *angustifolium* Vasey, in Bull. Torrey Club 13:165. 1886.

Paspalum laeve var. *brevifolium* Vasey, in Contr. U. S. Nat. Herb. 3:18. 1892.

Paspalum australe Nash in Britton, Man. 1039. 1901.

Paspalum circulare Nash in Britton, Man. 73. 1901.

Paspalum praelongum Nash in Small, Fl. Southeast. U.S. 74. 1903.

Paspalum laeve var. *australe* Nash in Hitchc. in Rhodora 8:205. 1906.

Paspalum laeve var. *circulare* Stone, in Ann. Rep. N.J. Mus. 1910:187. 1910.

Erect or ascending, tufted, glabrous to ciliate or pilose, perennial; culms slender and firm, 30-130 cm tall; leaves 5-30 cm long, 3-10 mm wide; racemes 2-7, usually 3 or 4, 4-17 cm long, ascending or spreading; rachis about 1 mm wide, with a tuft of hairs at base; spikelets solitary, glabrous, suborbicular to orbicular, 2.5-3.2 mm long, 2.0-2.5 mm wide; glume and sterile lemma 5-veined with the lateral veins approximate at the margins; fruit similar in shape and size to spikelet, the tip exposed at maturity.

Habitats. — Moist soils of roadside ditches, meadows, and stream borders.

Range.—Massachusetts to Kansas south to Texas and Florida.

Paspalum laeve can be distinguished from other Illinois taxa by its combination of a narrow rachis and a 5-veined sterile lemma.

Shape of spikelets, degree and location of pubescence, shape of leaves, and degree of spreading of racemes appear to be extremely variable characters. Chase (1929) and Hitchcock (1950), using these characters primarily, separated these plants into two species: *Paspalum laeve* Michx. and *P. circulare* Nash. In attempting to separate Illinois material, intermediates were found to be more numerous and no less homogeneous than those referable to the described species. Fernald (1950) assigned specimens with the more orbicular spikelets to *P. laeve* var. *circulare* (Nash) Fern.

Because variation in shape of the spikelets within individual specimens is frequently greater than between specimens, it appears undesirable to recognize *P. circulare* Nash or *P. laeve* var. *circulare* (Nash) Fern. in Illinois.

Specimens examined.—Alexander: one mile N of Tamms, *Winterringer 6029* (ISM). Bond: S of Greenville, *Winterringer 12953* (ISM). Cass: locality unknown, *Rexroat 479* (ISM). Champaign: S of Champaign, *Ahles 8453* (ISM). Clark: Rocky Branch, *Fuller 11001* (ISM). Clay: three miles N of Flora, *Winterringer 2154* (ISM). Clinton: E of Bartelso, *Winterringer 12967* (ISM). Coles: Lincoln Log Cabin State Park, *Voigt 954* (SIU). Crawford: NE of Robinson, *Winterringer 2983* (ISM). Cumberland: N of Neoga, *Winterringer 3376* (ISM). Edwards: Albion, *Winterringer 2139* (ISM). Effingham: E of Teutopolis, *Winterringer 9726* (ISM). Fayette: one mile SW of Laclede, *Evers 58265* (ILLS). Franklin: S of Ina, *Winterringer 3520* (ISM). Gallatin: three miles W of Omaha, *Evers 19901* (ILLS).

Hamilton: N of McLeansboro, *Evers 8644* (ILLS). Hardin: near Herod, *Winterringer 2413* (ISM). Jackson: Thompson Lake, SW of Carbondale, *Swayne & Bailey 518* (SIU). Jasper: five miles S of Newton, *Winterringer 2140* (ISM). Jefferson: W of Waltonville, *Boewe s. n.* (ILLS). Johnson: E of Vienna, *Evers 40747* (ILLS). Lawrence: SW of Birds, *Evers 19796* (ILLS). Madison: W of Hamel, *Winterringer 13006* (ISM). Marion: near Patoka, *Winterringer 3503* (ISM). Mason: S of Havana, *Rexroat 4210* (ISM). Massac: E of Midway, *Evers 52535* (ILLS). Monroe: S of Monroe, *Evers 7980* (ILLS). Morgan: three miles NE of Meredosia, *Rexroat 2062* (ISM). Perry: four miles W of DuQuoin, *Bell s. n.* (SIU). Pope: W of Dixon Springs, *Evers 20014* (ILLS). Pulaski: S of Ullin, *Evers 49994* (ILLS). Randolph: NE of Bremen, *Evers 7925* (ILLS). Richland: eight miles NW of Olney, *Shaw 757* (ISM). St. Clair: locality unknown, *Brendel 1914* (ILL). Saline: S of Harrisburg, *Winterringer 6031* (ISM). Shelby: NE of Sigel, *Boewe s. n.* (ILLS). Union: near Dongola, *Mohlenbrock 5517* (SIU). Wabash: S of Mt. Carmel, *Winterringer 9764* (ISM). Washington: four miles S of Nashville, *Evers 7871* (ILLS). Wayne: Cisne, *Carter 14120* (ISM). White: near Norris City, *Winterringer 3635* (ISM). Will: locality unknown, *Pepoon & Barrett 4399* (ILLS). Williamson: Crab Orchard Lake, *Sands & Garrison 325* (SIU).

6. *Paspalum lentiferum* Lam. Tabl. Encycl. 1:175. 1791.
Paspalum lanuginosum Willd. ex Steud. Nom. Bot. ed. 2. 2:271. 1841, in synon.
Paspalum curtisianum Steud. Syn. Pl. Glum. 1:26. 1854.
Paspalum praecox var. *curtisianum* Vasey, in Bull. Torrey Club 13:165. 1886.
Paspalum glaberrimum Nash in Small, Fl. Southeast. U.S. 76. 1903.
Paspalum tardum Nash in Small, Fl. Southeast. U.S. 77. 1903.
Paspalum kearneyi Nash in Small, Fl. Southeast. U.S. 77. 1903.
Paspalum amplum Nash in Small, Fl. Southeast. U.S. 77. 1903.

Erect, rather robust, usually glabrous; culms to 1.5 m tall; leaves to 25 cm long, to 7 mm wide, pilose, the sheaths pilose and strongly keeled; racemes 4-5, spreading-ascending; rachis slender, 1.5-2.0 mm wide; spikelets paired and solitary in the same raceme, suborbicular, 2.7-3.4 mm long, the glume and sterile lemma delicate.

Habitat.—Wet roadside ditch.

Range.—Virginia to Florida and Texas; Illinois.

This recent addition to the flora of Illinois occupies several square feet in a moist roadside ditch near Karnak in Pulaski County. The great distance from its nearest station indicates that it is probably adventive. It has persisted and spread for at least two years.

Specimen examined.—Pulaski: near Karnak, *Boyce s. n.* (SIU).

7. *Paspalum ciliatifolium* Michx. Fl. Bor. Amer. 1:44. 1803.
Paspalum pubescens Muhl. in Willd. Emum. Pl. 89. 1809.
Paspalum spathaceum Desv, ex Poir, in Lam. Encycl. Suppl. 4:314. 1816.
Paspalum latifolium LeConte, in Journ. de Phys. 91:284 . 1820.
Paspalum ciliatifolium var. *brevifolium* Vasey, in Proc. Acad. Phila. 1886:285. 1886.
Paspalum setaceum var. *ciliatifolium* Vasey, in Contr. U.S. Nat. Herb. 3:17. 1892.
Paspalum chapmani Nash, in Bull. N.Y. Bot. Gard. 1:290. 1899.
Paspalum eggertii Nash, in Bull. N.Y. Bot. Gard. 1:434. 1900.
Paspalum stramineum Nash in Britton, Man. 1:74. 1901.
Paspalum bushii Nash in Britton, Man. 1:75. 1901.
Paspalum muhlenbergii Nash in Britton, Man. 1:75. 1901.
Paspalum blepharophyllum Nash in Small Fl. Southeast. U.S. 1903.
Paspalum epile Nash in Small, Fl. Southeast. U.S. 72. 1903.
Paspalum pubescens var. *muhlenbergii* House, in N.Y. State Mus. Bull. 243-244:39. 1923.

Erect or spreading, tufted, glabrous to ciliate or pilose, perennial; culms slender, appressed, 35-100 cm tall; leaves 6-35 cm long, 2-20 mm wide; racemes 1-3, rarely 4, slender, arching; rachis slender, 1.0-1.2 mm wide, with a tuft or hairs at the base; spikelets in pairs, glabrous, shiny, suborbicular, 1.9-2.2 mm long, 1.3-1.7 mm wide; glume and sterile lemma 3-veined, the mid-vein frequently obscure; fruit similar in size and shape to spikelet.

Habitat.—Dry or moist sandy soils.

Range.—Vermont to Minnesota south to Colorado, Arizona, and Florida.

Paspalum ciliatifolium may be distinguished by its very small spikelets and its sterile lemma with 3 veins.

Chase (1929) and Hitchcock (1950) differentiate among, and assign species status to, *P. stramineum*, *P. pubescens*, and *P. ciliatifolium* primarily on the bases of the relative density of hairs on the blades and of the presence or absence of minute pubescence on the spikelets. Chase (1929) states, "To place *P. pubescens* as a subspecies of *P. ciliatifolium*, with *P. stramineum* and *P. supinum* under that as varieties, . . . would express an exactness of relationship that the facts do not at all warrant." Despite this warning, Fernald (1950), among others, gives status to *P. stramineum* and *P. pubescens* (the latter as var. *muhlenbergii*) as varieties of *P. ciliatifolium*.

Characters used to distinguish the several taxa were so variable among Illinois specimens examined that recognition of varieties of *P. ciliatifolium* in the state does not appear to be warranted.

Specimens examined. — Adams: two miles S. of Burton, *Brinker 3104* (ISM). Alexander: Cairo, *Chase & Beck 151* (ILL). Brown: locality unknown, *Rexroat 3360* (ISM). Calhoun: Hardin, *Chase & Beck 198* (ILL). Carroll: Thompson, *Winterringer 2753* (ISM). Cass: NW of Virginia *Rexroat 7198* (ISM). Champaign: Urbana, *Ahles 7431* (ISM). Clark: Marshall, *Chase & Beck 18* (ILL). Clay: Salt Pond, *Ahles 5134* (ILL). Clinton: E. of Albers, *Evers 54135* (ILLS). Coles: three miles S. of Charleston, *Fuller 12075* (SIU). Edwards: Albion, *Chase & Beck 58* (ILL). Fulton: S. of Banner, *V. Chase 2232* (ILL). Greene: NW part of the county, *Rexroat 7009* (ISM). Hamilton: S of McLeansboro, *Evers 51556* (ILLS). Hardin: E. of Karbers Ridge, *Evers 8479* (ILLS). Henderson: two miles W. of Oquawka, *Evers 58883* (ILLS). Henry: Colona, *Fell & Fell 46851* (ISM). Iroquois: Donovan, *Ahles 6884* (ISM). Jackson: one mile S of SIU campus, *Voigt 746* (SIU). Jasper: Newton, *Yeatter s. n.* (ILLS). Jefferson: S of Dix, *Evers 51757* (ILLS). Jersey: Pere Marquette State Park, *Evers 25022* (ILLS). Jo Daviess: SE of East Dubuque, *Evers 47494* (ILLS). Johnson: Vienna, *Ahles 6944* (ISM). Kankakee: E of St. Anne, *Graham 1904* (ISM). Lawrence: E of Billett, *Evers 34702* (ILLS). Lee: eight miles W of Maytown, *Evers 54573* (ILLS). McDonough: W of Macomb, *Myers C-1* (ISM). Macoupin: Carlinville, *Robertson s. n.* (ILLS). Madison: NW of Highland, *Evers 48922* (ILLS). Marion: locality unknown, *Menard s. n.* (ILL). Mason: Saidora, *Rexroat 6200* (ISM). Massac: Metropolis, *Chase & Beck 104* (ILL). Menard: Locality unknown, *Rexroat 5169* (ISM). Mercer: SE of Keithsburg, *Evers 48020* (ILLS). Monroe: W of Red Bud, *Chase & Beck 193* (ILL). Morgan: six miles S of Meredosia, *Rexroat 3029* (ISF). Peoria: Springdale Cemetery, *Cull s. n.* (ISM). Piatt: W of Monticello, *Evers 33770* (ILLS). Pike: S. of Chambersburg, *Rexroat 6557* (ISM). Pope: E of Dixon Springs, *Pepoon & Barrett 960* (ILLS). Pulaski: Grand Chain, *Chase & Beck 4143* (ILL). Putnam: Locality unknown, *Trojack 260R* (ISM). Rock Island: five miles N of Cordova, *Evers 6937* (ILLS). St. Clair: French Village, *Neill 1019* (ISM). Saline: locality unknown, *Pepoon & Foster 1403* (ILLS). Sangamon: Springfield Township, *Reeder 470* (ISM). Schuyler: Frederick, *V. Chase II 358* (ISM). Scott: NE of Naples, *Rexroat 3914* (ISM). Tazewell: eight miles W of South Pekin, *Evers 50846* (ILLS). Union: State Forest, *Fuller & Fisher 806* (ISM). Wabash; W of Allendale, *Evers 34730* (ILLS). Wayne: N of Cisne, *Evers 15677* (ILLS). White: N of Carmi, *Chase & Beck 4059* (ILL). Whiteside: N of Fulton, *Evers 54549* (ILLS). Will: two miles SE of Custer Park, *Swink 617* (ISM). Williamson: Crab Orchard Lake, *Sands & Garrison 326* (SIU). Winnebago: N of Shirland, *Fell 52-710* (ISM).

Species Excluded

Winterringer and Evers (1960) reported the occurrence of *Paspalum notatum* Flugge in Illinois, based upon a specimen collected from a stripmine in St. Clair County on June 29, 1950, by Alten Grandt. The specimen is deposited in ILL.

Examination of this specimen by the senior author shows it to be clearly *P. pubiflorum*. The spikelets are slightly pubescent, atypical for *P. pubiflorum* var. *glabrum*. There are 8 racemes as opposed to 2-3 in *P. notatum;* the incomplete culm is

nearly 1 m long, as opposed to 50 cm; the spikelets appear to be arranged in 4 rows rather than 2; the spikelets are more ovoid than in *P. notatum*. Thus, on the basis of this specimen, this southern grass can not be included in the flora of Illinois.

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Manuscript received June 11, 1965.

RADIOCARBON DATES FROM ALTONIAN AND TWOCREEKAN DEPOSITS AT SYCAMORE, ILLINOIS

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ABSTRACT.—Two radiocarbon dates have been determined for wood collected from an exposure in a gravel pit in the valley of East Branch Kishwaukee River at the northern edge of Sycamore, Illinois. Wood chips in the lower part of the exposure collected from pinkish gray outwash, part of the youngest drift of the Altonian Substage, were dated as older than 32,000 years B.P. (W-1382). A log near the top of the exposure in a lenticular black organic silt deposited during the Twocreekan Substage was dated at 12,000 ± 400 radiocarbon years B. P. (W-1385).

Excavation of a gravel pit just north of Sycamore, Illinois, examined in 1959, exposed a sequence of Pleistocene deposits that included sand and gravel outwash and organic silt containing wood fragments and logs. Wood found in two of the units was dated by the laboratories of the U. S. Geological Survey, Washington, D. C., and the dates, along with subsurface stratigraphic information on the region, are the basis for the present interpretations.

LOCATION AND GENERAL SETTING

The Larson gravel pit is in DeKalb County, about one-half mile north of Sycamore in the NE¼ NE¼ SW¼ sec. 29, T. 41 N., R. 5 E. (Fig. 1). It is located on the flood plain of the East Branch Kishwaukee River about 200 feet north of the river and west of a north-south township road and an abandoned railroad bed. The valley at this point is about three-fourths of a mile wide, is generally flat, and has a channel about 15 feet deep and 50 feet wide that contains the present stream. Little or no terracing appears to be present. A bedrock valley lies directly under the present valley north of Sycamore and is filled with glacial deposits to a level above that of the bedrock uplands on either side. The surficial deposits in the valley consist of outwash sand and gravel with a locally thick cover of alluvium.

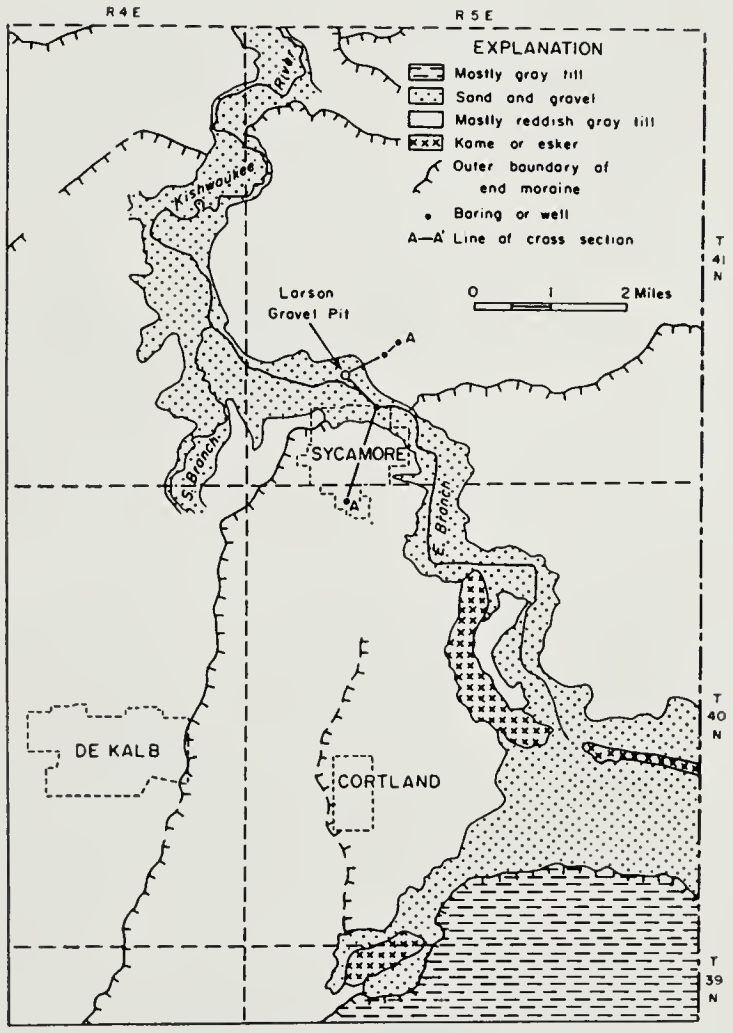


Figure 1.—Surficial map of the Sycamore, Illinois, area (modified from Anderson, 1964) showing position of Larson gravel pit north of Sycamore, nature and distribution of glacial deposits, and position of cross section shown in figure 3.

Stratigraphy

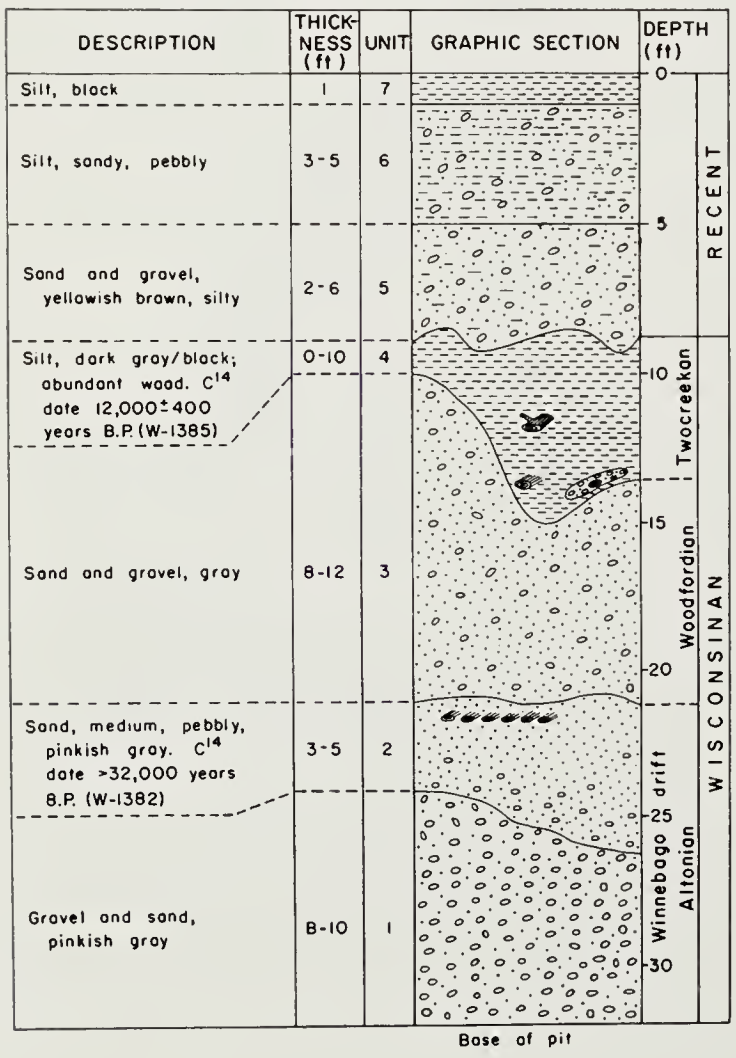
The stratigraphic sequence exposed in the west face of the gravel pit is illustrated in Figure 2. The deposits, from the base upward, consist of sand and gravel, gray with a pinkish cast and containing a few wood chips near the top (Units 1 and 2); gray sand and gravel with a distinct unconformity at the top (Unit 3); dark brownish gray to black organic silt containing abundant logs, twigs, leaf imprints, and lenses of sand and gravel (Unit 4); and yellowish brown sand and gravel (Unit 5) with numerous clam shells, becoming pebbly sandy silt (Unit 6), with black silt (surface soil) (Unit 7) at the top. The materials in the upper 5 feet of the section do not effervesce in hydrochloric acid, and the black organic silt reacts very weakly.

The distinct pinkish gray hue of Units 1 and 2, in contrast to the decided gray of Unit 3, clearly distinguishes them in the field. A handful of wood chips collected along a bedding plane in the upper foot of Unit 2 was reported as older than 32,000 radiocarbon years B.P. (W-1382). Although no pronounced unconformity was noted at the top of Unit 2, the bedding did appear to be truncated by the sand and gravel of Unit 3. Unit 3, as viewed in the north face of the pit, appears distinctly cross-bedded with the general dip westward. The top of Unit 3 exhibits the most pronounced unconformity within the sequence, with a maximum of about 10 feet of relief around the pit and obviously truncated bedding.

The black organic silt (Unit 4) is traceable in nearly all exposed faces of the pit but in many places thins to a few inches, or locally to a film. It was best developed along the west face of the pit, where it attained a maximum thickness of about 10 feet. The logs were found only in the lower half of the thick parts of the silt and in the rusty yellow sand and gravel lenses near the base of the unit. All of the logs more than about 6 inches in diameter were decidedly oval in cross section and appeared to have been flattened. To one or two of them, short lengths of branches were still attached. Numerous leaf imprints, twigs, and small woody fibers were discovered in the silt. One of the logs, about 6 inches in diameter, was collected and a portion submitted for radiocarbon dating. This wood was found to be 12,000 ± 400 radiocarbon years old (W-1385).

At the top of the silt a marked erosional unconformity has as much as 2 or 3 feet of relief. The sand and gravel directly above the organic silt contains numerous small clam shells that are neither worn nor broken. Unit 6 appears to be gradational from Unit 5, although the gravel is restricted to Unit 5.

Figure 2.—Stratigraphic section exposed in the Larson gravel pit.



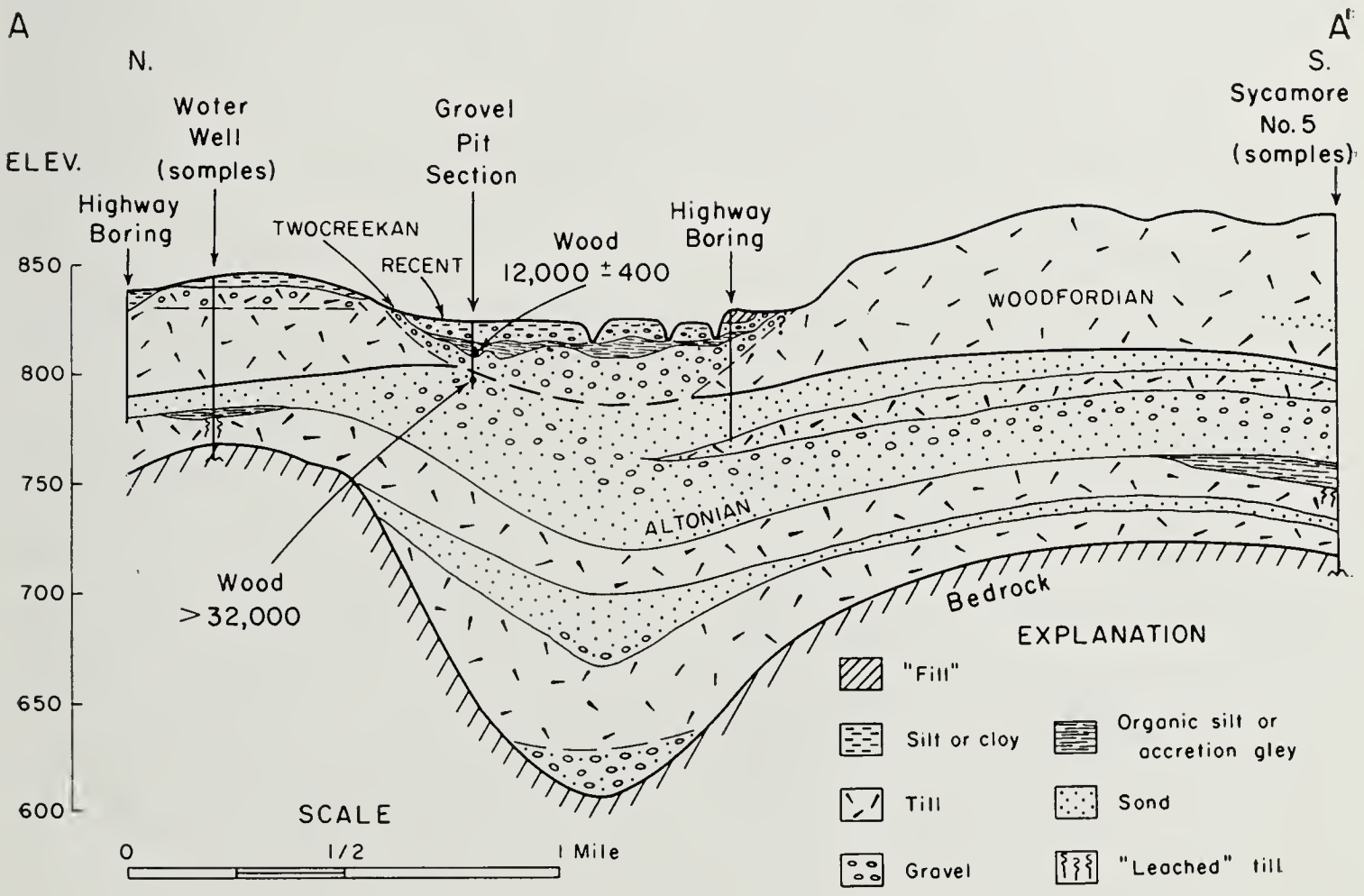
Age and History of Deposits

Radiocarbon dates obtained from the wood collected from Units 2 and 4 are useful in relating the deposits in the gravel pit to sequences elsewhere in the region. A distinct division between glacial and postglacial deposits is also established by the dates. Units 1, 2, and 3 are of definite glacial origin, but Units 4, 5, 6, and 7 were deposited after the continental glaciers had receded from the region.

Figure 3 shows the stratigraphic setting of the glacial deposits. The subsurface information from the immediate vicinity of the gravel pit and extension of other subsurface data and radiocarbon dates in the region show that four tills are present, the three lower tills Altonian in age. A date of 38,000± 3000 radiocarbon years B.P. (I-847) was obtained from peat sampled in a boring made about 16 miles to the northeast (Kempton and Hackett, 1963). This peat is at the same stratigraphic position—above the two lower tills —as the organic silt and accretion-gley penetrated by the two water wells shown on Figure 3. The thin reddish brown till and its related outwash, which are above the organic deposits, are therefore less than 38,000 years old. The reddish brown till and associated outwash were previously considered early Woodfordian in age (Kempton, 1963). Units 1 and 2 of the gravel pit section are considered to be Altonian outwash and are included in the Winnebago drift on the basis of the subsurface stratigraphy (Fig. 3) and the radiocarbon date of greater than 32,000 years B.P. that was obtained from the wood chips collected from Unit 2.

The earliest Woodfordian glacier covered the entire area shown in Figure 1 and deposited as much as 80 feet of reddish gray till. At the gravel pit the Woodfordian till was probably entirely eroded before the deposition of the younger outwash. As a later Woodfordian glacier advanced to the position of the morainic ridges south and southeast of Cortland (Fig. 1), which are correlated with the Cropsey Moraines in central Illinois, outwash from this glacier deposited a valley train along East Branch (Anderson, 1964). Bor-

Figure 3.—North-south cross section showing relation of subsurface sequence to gravel pit section. Wood dates are expressed in radiocarbon years before present.



ing samples and exposures of the till in the morainic ridges and in the ground moraine southeast of these ridges show a gray to brownish gray drift overlying the reddish gray drift of the earlier Woodfordian advance. The gray sand and gravel (Unit 3) exposed in the gravel pit was derived from the later Woodfordian glacier.

The age of the Woodfordian advances is not precisely known, as datable organic material directly related to these advances has not yet been found in this area. The earliest advance probably reached this area sometime after the Mississippi River was diverted into its present course, about 21,000 radiocarbon years B.P. (Glass, Frye, and Willman, 1964). The later advance to the moraine southeast of Cortland occurred after the earlier Woodfordian moraines were built but before the end of the Woodfordian, about 12,500 years ago (Frye and Willman, 1960).

Erosion of the outwash valley train by East Branch during the later part of the Woodfordian is shown by the highly irregular upper surface of Unit 3. Erosion of the sand and gravel must have been completed shortly before deposition of the overlying organic silt as no indication of weathering of Unit 3 was noted.

A period of relatively dense vegetation growth probably began along East Branch with the climatic change at the end of the Woodfordian (12,500 years B.P.) and continued during the Twocreekan Substage. During flood times East Branch deposited organic silt, logs, and vegetal materials (Unit 4) over the eroded surface of the valley train. The date of 12,000± 400 radiocarbon years B.P. from one of the logs establishes a Twocreekan age for the deposit, the first Twocreekan date determined for deposits in Illinois. In Wisconsin the Two Creeks forest bed was flooded by Lake Chicago 11,840 radiocarbon years B.P. when the Valderan glacier crossed the Straits of Mackinac (Broecker and Farrand, 1963).

The deposits overlying the organic silt (Units 5, 6, and 7) are alluvium deposited during the Recent Stage, which began about 5,000 radiocarbon years ago. The upper three units in the vicinity of the gravel pit apparently form the nearly level floor of the present valley.

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Manuscript received July 2, 1965.

PETROGRAPHY OF DEVONIAN PHOSPHATES OF INDIANA

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ABSTRACT.—In the Devonian rocks of Indiana phosphate occurs in thin bands either as an in situ replacement of limestones, or as a detrital constituent. Although some phosphate is nearly opaque and without recognizable texture, much is oolitic, with the ooliths having textures similar to their carbonate counterparts. Mineral associations include glauconite, pyrite, dolomite, calcite, and some fluorite. The phosphates are underlain by well sorted limestones and overlain, firstly by beds rich in crinoids to be followed by beds with bryozoa. It is concluded that these phosphate bands result from phosphate enrichment of the waters during regressions of the Devonian seas.

The occurrence of calcium phosphate in rocks of Devonian age aroused some interest with the discoveries of commercial phosphate in Tennessee, made known by the work of Hayes (1896). Since then other occurrences have been reported from the Devonian of the midcontinent including Ohio (Westgate and Fisher, 1933) and Indiana (Campbell, 1946 and Murray, 1955).

In Indiana the phosphate beds are developed most extensively in the Sellersburg limestone of central Scott County. Their presence in strata of Jeffersonville age usually is in the form of thin impersistent bands of granular, sand-sized, detrital phosphate. In the Sellersburg beds, they occur as layers about 10 cm. thick, some of which are persistent for hundreds of yards; and such accumulations are noteworthy for their variety of textures. The most persistent occurrences of phosphate are directly below the New Albany Shale extending from the Meshberger quarries in the north to the Ohio River in the south.

PETROGRAPHY

The petrography of these Devonian phosphates is discussed under two headings: in situ occurrences and detrital occurrences.

In situ occurrences. — Phosphatic crusts on limestones have been recorded by Andersson (1896), Lamplugh (1889), Bristow (1889), and Hayes (1896), but the Devonian rocks studied here have only one good example exposed at a locality in Scott County (near Kent, about 10 miles west of Madison, Indiana). Here phosphate crusts, about 15 cm. thick display a hummocky upper surface and pass laterally and vertically into detrital phosphates described below. Transition between the phosphate and the underlying limestones is gradual, and is observed at the limestone end of the series as an initial development of phosphate along grain boundaries accompanied by the development of

secondary dolomite. Large syntaxial grains, granular rims, and fossil debris remain unaffected in this early stage, but with increasing phosphatization the cement or matrix is replaced gradually until only the organic debris remains. Although not seen in this occurrence a study of pebble phosphate (see below) suggests that the final product of the phosphatization is a rock composed wholly of light or dark brown phosphate studded with only the most resistant organic elements (e.g. crinoids), and detrital quartz grains.

Detrital occurrences. — Detrital phosphate probably is the most common occurrence in the geological record and is certainly most frequently observed in the Devonian of Indiana. Much is in the form of pebbles ranging in size from 5-50 mm., usually well rounded; and, although some have a nodular appearance, are interpreted as of detrital origin as indicated by their sharply defined margins and distinctive textures.

Oolitic textures characterize many of the pebbles. Such ooliths, range in size from 0.2-0.5 mm.; are either ovaloid or spherical, and distinguished from the surrounding phosphate by their bright reddish colour. Inclusions of quartz, glauconite, calcite, and pyrite are common.

Pebbles composed of almost opaque phosphatic material seldom show any distinctive textures; in these varieties, however, pyrite is relatively common. Pebbles also occur with abundant relic organic remains of bryozoans, brachiopods, and crinoids. Generally the original calcite matrix has been replaced completely by phosphate, but from a study of a number of pebbles it is possible to describe the manner in which a fossil test is phosphatized and also record the relative susceptibility of each organism to this form of replacement. Bryozoans are amongst the earliest to show signs of replacement, and generally it is manifested by the infilling of the pores with phosphate; the wall structure, however, remains fairly resistant. Brachiopods also amongst the earliest to be replaced usually show uniformly phosphatized shells; whereas, crinoids (among the most resistant) have the wall structure replaced first, leaving the original pores filled with calcite.

Some of the pebbles are transected by thin veins of calcite which may enclose the phosphatic ooliths within the pebble so as to appear to release them from the main phosphate mass of the pebble.

Ooliths also occur commonly as discrete grains, usually 0.2-0.7 mm.; oval or spherical in cross section and consist of several concentric layers. When ovaloid they lie with their long axes parallel to the bedding, but both shapes are found as components of laminated or cross laminated limestones. Some ooliths have cores composed of rounded quartz grains, rounded or euhedral glauconite (cf. Dietz et al. 1943), microgranulose and single crystals of calcite, dolomite euhedra, francolite, and pyrite (either as a single grain or a cluster of several).

Concentric layering in many of the ooliths may be composed of alternations of light and dark collophane (cf. Carozzi 1960), or alternations of clear, brown collophane with layers of collophane crowded

with minute specks (of indeterminate nature); but, alternations of collophane and francolite, collophane and calcite, and collophane and pyrite are common. The configuration of such layering besides being concentric is sometimes eccentric (Fig. 1). Moreover, the initial shape of the core usually controls the final form of the oolith (as with calcareous ones). There are also examples of broken and re-coated ooliths similar to those described by Carozzi (1961, fig. 6) from limestones.

The dark layers of the ooliths are often areas of pyrite growth and replacement: in some examples the whole or one complete part of an oolith has been replaced by pyrite—the original banding being identifiable only in reflected light.

As with many phosphates broken and distorted ooliths are common in these examples (Fig. 1). There are two general types present: those which are broken by some force of impact, and those broken by forces related to diagenesis and compaction. Impact breakage of the ooliths is frequently of the type—group 1 of Carozzi (1961, p. 271-273) where the small circle of the oolith has collapsed, and is thought to have originated by the striking together of the oolith and other bodies. Compaction breakage occurs when other constituents of the rock penetrate the skins of the oolith with the result that there is an in situ collapse of the latter. When the outer dark skin is rigid (as is often the case) the oolith fractures into small fragments but the brown collophane behaves as a plastic medium with the result that it folds during deformation. In a few examples, destruction of the oolith is accompanied by a replacement of the collophane by calcite. The oolith may be at or near the center of a large calcite grain and its disintegration resembles the "exploding bomb" structure seen in geodes and described by Bassler (1908).

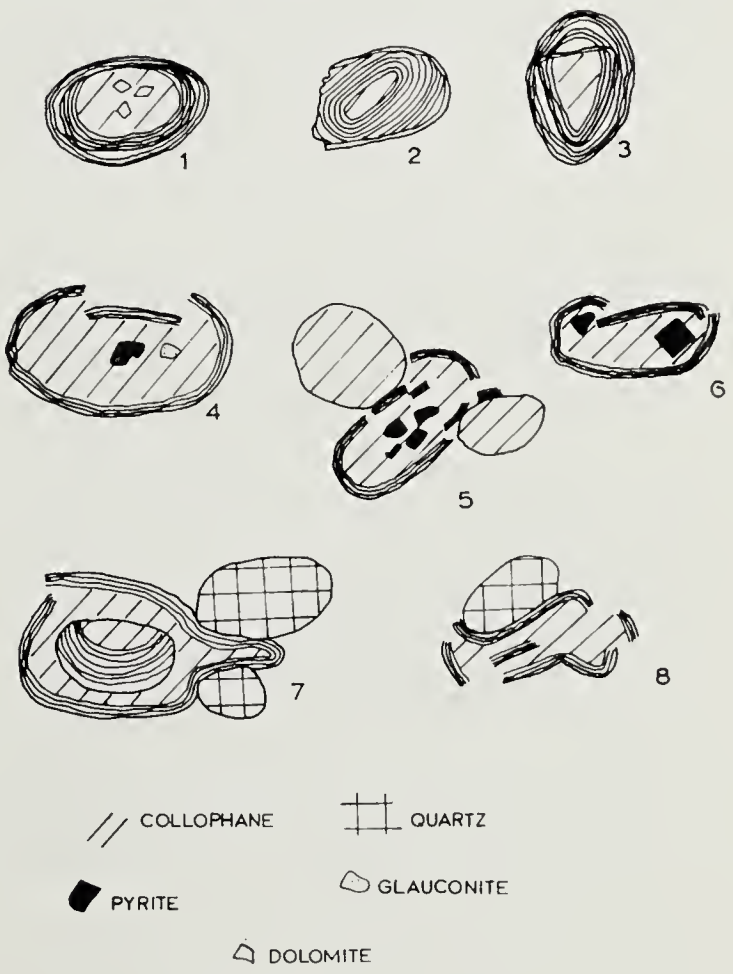
Other detrital phosphatic components include ovulites, fish remains and other organic debris.

Associations

The common associations of phosphate have been listed by Kazakov (1937) and Carozzi (1960).

Mineral associations. — Accessory minerals in the phosphates herein reported are numerous and intricate in their interrelations. Glauconite is fairly common, and is found replacing crinoids (cf. Carozzi 1960, p.

Figure 1.—Diagrams showing the disconformable layering in the ooliths (1, 2, 3) and the breakage by impact (4) and compaction (5, 6, 7, 8).



375), as isolated rounded grains, or as cores to collophane ooliths (where in some instances the glauconite replaces the surrounding collophane).

In common with most phosphates pyrite is abundant and occurs as a primary constituent of the limestone, as a nucleus for oolith development, and as a secondary mineral replacing individual ooliths (see p. 45) or the whole rock fabric (which may include the already pyritized ooliths).

Dolomite occurs either as euhedral grains zoned with brown iron-oxide inclusions or as a somewhat finer grained granoblastic variety. Dolomitization is believed to precede the 'front' of phosphatization in many of the examples where the latter process is or has been in operation.

Calcite is particularly abundant both as pre- and post-phosphate mineral. It occurs replacing some of the phosphate ooliths as described by Lowell (1952, p. 24). Fluorite is present in small amounts, but little is known about its age and origin.

Stratigraphic associations. — The association of phosphate with nonsequences is well known, and their occurrence at the bases of transgressions has been recorded by Kirkaldy (1939, p. 409) and Oakley (1941, p. 2). In the Indiana occurrences, the following succession is considered to prevail from the base upward (Fig. 2):

1. Beds of well sorted fragmental limestone (below the phosphate).
2. Phosphates, size graded upward and with comparatively large quartz grains.
3. Badly sorted fragmental limestone, relatively rich in crinoids.
4. Limestones which are comparatively rich in bryozoans.

This order of occurrence is interpreted to be the result of a marine regression during which 1 and 2 (above) were deposited, followed by a marine transgression during which 2 (above) was eroded, and 3 and 4 deposited. If the occurrences of phosphate bands indicate such cycles of events, then the maximum number of cycles observed in the Jeffersonville and Sellerburg is five (excluding the phosphate below the New Albany shale transgression).

Acknowledgments

It is with pleasure the author acknowledges the advice of Professor A. V. Carozzi, and the helpful criticism of the manuscript given by Professor T. N. George. A grant from the Graduate College of the University of Illinois defrayed the expense of field work.

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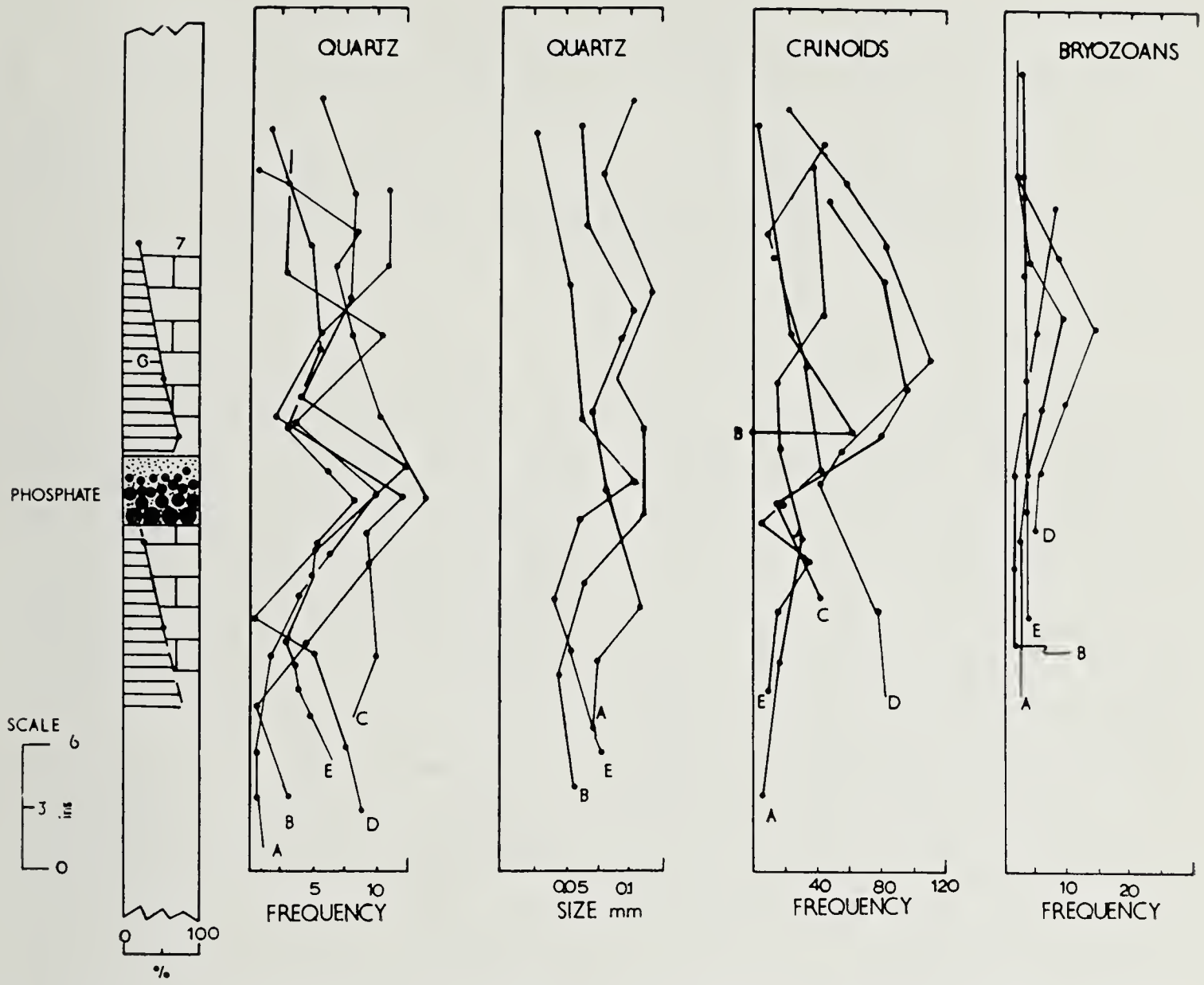

Figure 2.—Variations in composition and lithology across the phosphate bands. The distribution of lithological types, given in the column on the left, is an average for all the phosphate beds studied; and 6 is a poorly sorted limestone, 7 is a well sorted limestone. A refers to a section in Meshberger Quarry; B, C, and D to Paul Frank Quarry, E to Scott County Quarry.

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Manuscript received May 3, 1965.

AN IODINE-METHYL SULFOXIDE PRECIPITATE

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ABSTRACT.—The precipitate formed when I_2 and DMSO solutions are mixed is found to be preferentially solvated by DMSO. The solvation occurs in a manner which is predictable by a linear relation. The experimental evidence supports a 1:1 reaction.

In a solubility study of iodine in methyl sulfoxide (commonly called dimethylsulfoxide and designated DMSO) Jones and Musulin (1959) noted the formation of an unexpected precipitate at 45°C. The purpose of the present study was to investigate the nature of that precipitate at room temperature.

EXPERIMENTAL

Reagents. DMSO, supplied gratis by the Stepan Chemical Company, was purified by distillation with the recovery of a one degree boiling fraction which was stored in a dried glass flask stoppered with a foil covered cork. Resublimed iodine, Mallinckrodt A. R. grade, and carbon tetrachloride, Fisher A. C. S. grade, were used without further purification.

Procedure. Stock solutions of 0.1 M I_2 and 0.1 M DMSO (using carbon tetrachloride as a solvent) and a standard solution of 0.1 M $Na_2S_2O_3$ were prepared. Weighings were made on a Christian Becker, Model AB-2, Chainomatic balance while all volumetric measurements were made with 0.1, 1, and 10 ml uncalibrated pipets. Four different solutions and one check solution were prepared by mixing different ratios of the two stock solutions. The compositions of the new solutions (hereafter called I_2-DMSO solutions) are given in Table 1.

A black precipitate was formed upon the preparation of the I_2-DMSO solutions. Each precipitate was separated from its solution, dried and weighed. The weight of iodine in the precipitate was determined by a titration procedure using the standard $Na_2S_2O_3$ solution. The weight of the DMSO in the precipitate was determined by difference. The decantate was also titrated with standard $Na_2S_2O_3$ solution in order to provide a check on the procedure.

RESULTS

The results, in terms of mole ratios, n(DMSO)/n (I_2), are given in Figure 1. These results show that this experiment does not give a fixed empirical formula for the precipitate. If the mole ratio in the precipitate is plotted as a function of the mole ratio in the original I_2-DMSO

Figure 1.—The mole ratio in the precipitate as a function of the mole ratio in I_2-DMSO solutions.

solution, an excellent linear relation is obtained as can be seen from Figure 1. The equation of this line, found by a method of least squares (Scarborough, 1958), is

$$\left[\frac{n(DMSO)}{n(I_2)}\right]_{ppt} = 0.69\left[\frac{n(DMSO)}{n(I_2)}\right]_{soln} + 1.25 \quad (1)$$

The fitting procedure did not include the point for solution I. The standard deviation of the ordinate values given by Equation (1) is 0.05. Table 1 shows the individual deviations.

Discussion

Equation (1) can be interpreted as indicating that molecules of DMSO are solvating the precipitate. That is,

$$aI_2 + (b + c)\ DMSO \rightarrow [(I_2)_a : (DMSO)_b] \cdot [DMSO]_c \quad (2)$$

where c represents the number of moles of solvating DMSO. In writing the reaction given by Equation (2) no claim is made as to whether a definite chemical reaction such as substitution, etc., has taken place or whether a molecular complex has been formed. The fact that Equation (1) is so definitely linear would indicate that as excess DMSO (in relation to the I_2) is added to an I_2-DMSO solution, a fixed amount would solvate any precipitate which has been formed. Obviously these same arguments would hold if one wished to interpret c as the amount of DMSO occluded in a precipitate crystal lattice. Finally, this interpretation would indicate a preferential solvation (or ability to be occluded) by the DMSO in relation to the solvent, CCl_4. Such behavior is not strange if one considers the differences in DMSO and CCl_4 as a Lewis base (Gould, 1962).

The intercept of Equation (1) establishes an upper limit for the ratio b/a of the subscripts appearing in Equation (2). However, one would expect a minimal amount of solvation in any precipitation reaction which would indicate that this upper limit is too high. Musulin, et. al. (1964) suggest (from spectrophotometric evidence) that the ratio b/a

Table 1.—I_2-DMSO Solution Data.

Solution Designation	Volume of 0.1 M I_2 Solution (ml)	Volume of 0.1 M DMSO Solution (ml)	Weight of Precipitate (mg)	Volume of 0.1 M $Na_2S_2O_3$ Solution (ml)	Weight of I_2 in Precipitate (mg)	Volume of 0.1 M $Na_2S_2O_3$ Decantate (ml)	$\left[\frac{n(DMSO)}{n(I_2)}\right]_{ppt}$ (Calculated)	Deviation
I	10	10	138.3	7.4	93.60	12.25	1.94	.39
Ia	10	10	209.2	10.19	128.90	5.30	1.94	—.08
II	5	20	115.5	4.07	51.48	5.90	4.01	—.03
III	20	5	79.5	4.40	55.00	33.30	1.42	+.02
IV	10	20	226.7	9.97[1]	126.05[1]	9.85	2.63	+.05

[1] Back calculated.

should be 1. The current investigation supports a 1:1 reaction if one considers the product solvated.

Acknowledgment

The authors wish to thank the Illinois State Academy of Science for support during the course of this investigation.

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Manuscript received April 5, 1965.

THE CONSTITUTIVE NATURE OF THE POLYMER BOND

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ABSTRACT.—A new constitutive effect is proven to be necessary to differentiate between solutions of monomers and solutions of polymers in work using additive-constitutive properties. Numerical results are presented for some typical examples. A brief discussion of the implications of the new effect is presented.

Additive and constitutive properties have long been used to deduce structural information concerning molecules (Partington, 1951). In general, contributions from atoms, groups, and chemical structure are used to determine the value of the property being studied for a given molecule. That is,

$$P = \Sigma P_g + \Sigma P_s \qquad (1)$$

where P is the property being studied (e.g. parachor, molar refraction, etc.), P_g is the value of that property for a group or atom, and P_s is the value of that property for a specific type of chemical structure. The adjective *additive* refers to the contributions, P_g; the adjective *constitutive* refers to the contributions, P_s. Usually the terms P_s arise from multiple bonds, semipolar bonds, and various types of rings.

If, instead of studying the pure specie, the molecule is in solution, then *additive* is used in a second context; *viz.*, the value of the property, P, for the solution is found by adding, in their proper ratios, the P values for the components of the solution. In equation form

$$P = x_1P_1 + x_2P_2 \qquad (2)$$

where x is mole fraction and the subscripts, 1 and 2 refer to the solvent and solute, respectively.

The primary purpose of this work is to determine whether or not a constitutive contribution is necessary for a bond linking two or more identical molecules. For example, should the hydrogen bond in an acetic acid dimer give a constitutive contribution? Secondly, this paper presents a generalization of parachor work of Bhagwat and Toshniwal (1942). The generalized proof formalizes the intuitive feeling that if one does not attribute a constitutive nature to the polymer bond, then there is no way to differentiate (on the basis of additive-constitutive properties) between monomers and polymers in solution.

Before proceeding with the proof and calculations, some further notational remarks should be made. Each additive-constitutive property may be written as proportional to the solution molecular weight, M, *viz.*,

$$P \propto M$$

or

$$P = AM \qquad (3)$$

where the proportionality constant, A, contains experimentally measured information. For example, the parachor, [P], is given by

$$[P] = \frac{\gamma\ ¼}{d_l - d_v} M \qquad (4)$$

where γ is the surface tension, dl is the density of the solution, and d_v is the density of the vapor. The molar refraction, [R], is given by

$$[R] = \frac{n^2 - 1}{n^2 + 2}\ \frac{1}{d_l} M \qquad (5)$$

The property values for the solvent, P_1, and the solute, P_2, may also be found from formulas such as those given by Equations (4) and (5) if d_l is taken as the density of the pure liquid and the corresponding experimental values (surface tension or refractive index) are those of the pure liquid.

Throughout this paper the property value calculated with known atomic and structural values (Equation (1)) is designated by a subscript, C, e.g. P_C, and the property value found from experimental values is designated (Equation (3)) by a subscript, E, e.g. P_E. In order to distinguish between monomeric, dimeric, and polymeric units, an additional subscript is used. The additional subscript is m, d, or p when the discussion involves monomer, dimer, or polymer, respectively. For example, P_{Cm} is a calculated property value of a monomer and P_{2p} is a property value for polymeric solute.

The Necessary Condition

Suppose a particular solute is dissolved in a solvent and, further, suppose that it is not known whether the solute in solution contains monomeric, dimeric, or polymeric units. If the solute is in monomeric form, one writes Equation (2) as

$$P_{Cm} = x_{1m}P_1 + x_{2m}P_{2m} \qquad (6)$$

where the mole fractions in terms of the moles of solvent, n_1, and the moles of solute, n_2, are given by

$$x_{1m} = \frac{n_1}{n_2 + n_1} \qquad x_{2m} = \frac{n_2}{n_2 + n_1} \qquad (7)$$

and the terms P_1 and P_{2m} are found from tables of the property value. On the other hand, if the solute exists in solution in polymeric form, then Equation (2) becomes

$$P_{Cp} = x_{1p}\ P_1 + x_{2p}\ P_{2p} \qquad (8)$$

where, in terms of the moles of polymeric solute, n_2',

$$x_{1p} = \frac{n_1}{n_2' + n_1} \qquad x_{2p} = \frac{n_2'}{n_2' + n_1} \qquad (9)$$

If there are p monomeric units forming the polymer, then, by stoichiometry

$$n^{2\prime} = \frac{1}{p} n_2 \qquad (10)$$

Further, if the bonds linking the monomeric units contribute no new constitutive information (as is usually assumed), then

$$P_{2p} = pP_{2m} \qquad (11)$$

Substituting Equation (10) into Equation (9) and putting that result plus Equation (11) into Equation (8), one obtains

$$P_{Cp} = \frac{pn_1}{n_2 + pn_1} P_1 +$$

$$\frac{n_2}{n_2 + pn_1} pP_{2m} \quad (12)$$

or

$$P_{Cp} = \frac{p}{n_2 + pn_1} [n_1P_1 + n_2P_{2m}] \quad (13)$$

The right-hand side of Equation (13) is not changed upon multiplication by 1, where

$$1 = \frac{n_2 + n_1}{n_2 + n_1}$$

The result is

$$P_{Cp} = \frac{p(n_2+n_1)}{n_2 + pn_1} [x_{1m}P_1 + x_{2m}P_{2m}] \quad (14)$$

or, combining Equation (14) with Equation (6),

$$P_{Cp} = \frac{p(n_2 + n_1)}{n_2 + pn_1} P_{Cm} \quad (15)$$

It is usually true in solution experiments that the molecular weight is an additive function, i.e.

$$M = x_1M_1 + x_2M_2 \quad (16)$$

where M_1 and M_2 are the molecular weights of the solvent and solute, respectively. Since Equation (16) is simply a particular case of Equation (2), it follows that

$$M_{Cp} = \frac{p(n_2 + n_1)}{n_2 + pn_1} M_{Cm} \quad (17)$$

Equation (3) specialized for the monomer is

$$P_{Em} = AM_{Cm} \quad (18)$$

and specialized for the polymer is

$$P_{Ep} = AM_{Cp} \quad (19)$$

Combining Equations (17), (18), and (19) one obtains

$$P_{Ep} = \frac{p(n_2 + n_1)}{n_2 + pn_1} P_{Em} \quad (20)$$

In the use of additive-constitutive properties, it is usually assumed that the calculated and experimental values of the property will agree to within 2 or 3% if the structural formulation is correct. However if this assumption is applied in this problem, i.e.

$$P_{Cp} = P_{Ep} \quad (21)$$

then, using Equations (15) and (20), one obtains

$$\frac{p(n_2 + n_1)}{n_2 + pn_1} P_{Cm} = \frac{p(n_2 + n_1)}{n_2 + pn_1} P_{Em} \quad (22)$$

Equation (22) gives no further information than the usual assumption for monomers

$$P_{Cm} = P_{Em} \quad (23)$$

The implication of Equation (22) is that no matter how weak the interaction between monomeric units, some constitutive information concerning the link must be used if the property value for the polymer is to reflect any additional information than can be obtained from property value information of the monomer. Intuitively the result is obvious but the preceding derivation puts the intuition on firm footing. Previously Bhagwat and Toshniwal (1942) proved that the equation of Hammick and Andrew (1929) held for associated molecules. Whereas that

proof, in a different manner, established the conclusion of Equation (22) for parachors of dimers, the present proof shows the generality of the conclusion for all additive-constitutive properties and extends the conclusion to polymers.

A New Constitutive Contribution

One method of insuring that the property value of the polymer differs from that of the monomer is to specifically introduce a constitutive effect for the link between monomeric units. In the following it is assumed that all monomeric linkages in a given polymer are the same. The new effect is properly introduced by rewriting Equation (11) as

$$P_{2p} = pP_{2m} + qP_B \qquad (24)$$

where q is the number of identical linkages or bonds in the polymer and P_B is the new constitutive property value for a bond joining two monomeric units. If Equation (24) is used in the derivation of the preceding section, instead of Equation (11), one obtains in place of Equation (22) (or the equivalent Equation (23))

$$P_{Em} = P_{Cm} + \frac{q}{p} x_{2m}P_B \qquad (25)$$

Numerical Results

Equation (24) is tested with selected parachor and molar refraction data for associated liquids dissolved in non-associated liquids. A summary of the results is given in Tables 1 and 2. In these calculations p and

Table 1.—Dimer Bond Parachors.[1]

Solute-Solvent	x_{2m}	$[P]_{Em}$[2]	$[P]_{Cm}$[3,4]	% Deviation	$[P]_B$[5]	$[P]'_{Cm}$[6]	% Deviation
CH_3COOH-C_6H_6	.279	186.6	184.74	1.00	13.33	185.8	.42
	.510	168.9	167.06	1.09	7.22	169.0	—.07
	.820	145.6	143.33	1.56	5.54	146.5	—.62
	1.000	131.9	129.55	1.78	4.70	133.4	—1.14
				1.36[7]	7.70[7]		—0.36[7]
C_2H_5OH-C_6H_6	.237	187.8	186.87	.50	7.85	187.3	.27
	.564	161.4	160.33	.66	3.79	161.4	.00
	.758	145.4	144.59	.56	2.14	146.1	—.48
	1.000	126.0	124.95	.83	2.10	126.9	—.71
				.64[7]	3.97[7]		—.23[7]
$(CH_3)_2CO$-C_6H_6	.2993	193.1	191.11	1.03	13.30	192.6	.26
	.5283	182.3	179.63	1.46	10.11	182.3	.00
	.7034	174.1	170.86	1.86	9.21	174.4	—.17
	.8563	166.9	163.20	2.22	8.64	167.5	—.36
	1.0000	160.2	156.00	2.62	8.40	161.0	—.50
				1.84[7]	9.93[7]		—.15[7]

[1] All values in units of dynes $^{1}/_{4}$ $cm^{-1/4}$ cm^3.
[2] D. L. Hammick and L. W. Andrew (1929).
[3] The bond parachors used in this calculation are the revised values given by Vogel, et al. (1950).
[4] From Equation (2).
[5] From Equation (25).
[6] Calculated from $[P]_{Cm} + \frac{x_{2m}}{2} [P]_B$.
[7] Average values.

TABLE 2.—Dimer Bond Refractions.

Solute-Solvent	x_{2m}	$[R]_{Em}$	$[R]_{Cm}$[1]	% Deviation	$[R]_{B}$[2]	$[R]'_{Cm}$[3]	% Deviation
i-C_3H_7CH-*n*-C_6H_{14}[4]	.17920	27.55	27.54	.04	.112	27.54	.04
	.33283	25.69	25.68	.04	.060	25.69	.00
	.47034	24.02	24.02	.00	.000	24.03	—.04
	.59009	22.58	22.57	.04	.029	22.58	.00
	.69742	21.27	21.28	—.05	—.029	21.29	—.09
	.79276	20.12	20.12	.00	.000	20.13	—.05
	.87858	19.08	19.07	.05	.023	19.09	.05
	1.00000	17.62	17.58	.23	.080	17.60	.11
				.04[5]	.034[5]		.00[5]
CH_3OH-CCl_4[6 7]	.26886	22.477	21.256	5.43	9.083	22.105	1.66
	.51242	18.435	16.872	8.48	6.100	18.491	—.30
	.73074	14.345	12.966	9.61	3.774	15.275	—6.48
				7.84[5]	6.319[5]		—1.71[5]
CH_3OH-C_6H_6[6 7]	.25186	21.116	21.650	—2.53	—4.240	21.283	—.79
	.49387	16.559	17.283	—4.37	—2.932	16.564	—.03
	.72871	12.476	13.044	—4.55	—1.559	11.984	3.94
				—3.82[5]	—2.910[5]		1.04[5]
CH_3OH-C_6H_6[7 8]	.12988	23.901	23.852	.21	.755	23.876	.10
	.13461	23.798	23.767	.13	.461	23.792	.03
	.25397	21.684	21.612	.33	.567	21.658	.12
	.26234	21.525	21.461	.30	.488	21.509	.07
	.36777	19.642	19.558	.43	.457	19.625	.09
	.36893	19.626	19.538	.44	.477	19.606	.10
	.49280	17.392	17.302	.52	.365	17.392	.00
	.49342	17.288	17.201	.50	.353	17.291	—.02
	.61696	15.155	15.061	.62	.305	15.174	—.13
	.62142	15.076	14.981	.63	.306	15.095	—.13
	.74600	12.828	12.732	.75	.257	12.869	—.32
	.74890	12.776	12.680	.75	.256	12.817	—.32
	.74979	12.755	12.664	.71	.242	12.801	—.36
	.87456	10.501	10.412	.85	.203	10.572	—.68
	.87755	10.446	10.358	.86	.201	10.519	—.70
	1.00000	8.231	8.148	1.01	.166	8.331	—1.21
				.57[5]	.366[5]		—.21[5]

[1] From Equation (2).
[2] From Equation (25).
[3] Calculated from $[R]_{Cm} + \frac{x_{2m}}{2} [R]_B$.
[4] Experimental data from Böttcher (1952), p. 269.
[5] Average values.
[6] Calculated from experimental data given by Scatchard and Ticknor (1952).
[7] Bond refractions taken from Ref. 3, Table 1.
[8] Calculated from experimental data given by Wood, et al. (1960)

q were assumed to be 2 and 1, respectively. In every case a significant improvement was obtained in the calculated property values. Further, in one case where results from two workers can be compared (CH_3OH in C_6H_6), the average values of P_B are of the same magnitude. In several cases, P_B shows a definite variation with x_{2m} which might indicate a solvation effect. However, the present data does not warrant

the usual extrapolation to infinite dilution. In fact, the term P_B is equivalent to replacing the finite series defining Scatchard's excess function (Scatchard, 1949) by a single term. The variation of P_B could well correspond to higher order terms in the series.

Batsanov (1961) has also suggested that the difference between experimental and calculated molar refractions can be attributed to hydrogen bond molar refractions. His work applies to both inorganic and organic compounds while the present paper provides the natural extension to solutions. Padova (1964) has calculated solvated molar refractions for electrolytic solutions. The present calculations show that solvation effects may be general for additive-constitutive properties.

Theoretical Rationale

The inclusion of constitutive effects for these weak bonds does, in fact, have some theoretical basis. Fowler (1937), using statistical mechanics and thermodynamics, has related parachor to a constant, B. The value of B is dependent upon interaction energy between molecules as well as a distribution function which is energy dependent. An omission of hydrogen bonding, charge transfer effects, etc., fails to fully utilize the information in B.

Any interaction, e.g., the dimerization of acetic acid, affects the energy of the system. The perturbation caused by the dimer bond formation alters the polarizability of the molecule. Since the polarizability is proportional to the mole refraction (Pauling and Wilson, 1935), a contribution to $[R]_{Cd}$ must be included. Although it is known that hydrogen bonding affects the dipole orientation, the resulting change in dielectric constant and dipole moment varies both in direction and magnitude (Pimental and McClellan, 1960). Consequently a value of $[R]_{Cd}$ depends upon the particular bond. The present proof emphasizes the consequences of omitting constitutive information, even for weak interactions.

Summary

The material in this paper is divisible into two principal parts. First, a mathematical proof is given concerning the necessity of including a constitutive factor to describe, with additive-constitutive properties, the type of bond linking two identical molecules in solution. One, intuitively, feels this is true when a strong polymer bond is formed. However, the present proof emphasizes the necessity of such a contribution even if the linkage is much weaker, e.g. a hydrogen bond or a charge transfer bond. An extremely important corollary to this proof is the fact that it is not possible to obtain additional independent mathematical conditions by writing equations involving the additive-constitutive properties of dimer, trimer, etc., in addition to the monomer equation.

Second, a new constitutive contribution is defined for systems containing linked identical molecules in solution. Numerical calculations are given to support the new proposal. Finally, a brief theoretical justification is given for the new contribution.

Acknowledgment

The author wishes to thank Mr. Jerry Drennan for performing some calculations which indicated the failure of Equation (21) to provide any new information.

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Manuscript received April 8, 1965.

MICRODETERMINATION OF SULFUR AND HALOGENS IN NONVOLATILE SUBSTANCES IN SOLUTION BY THE SCHÖNIGER FLASK METHOD

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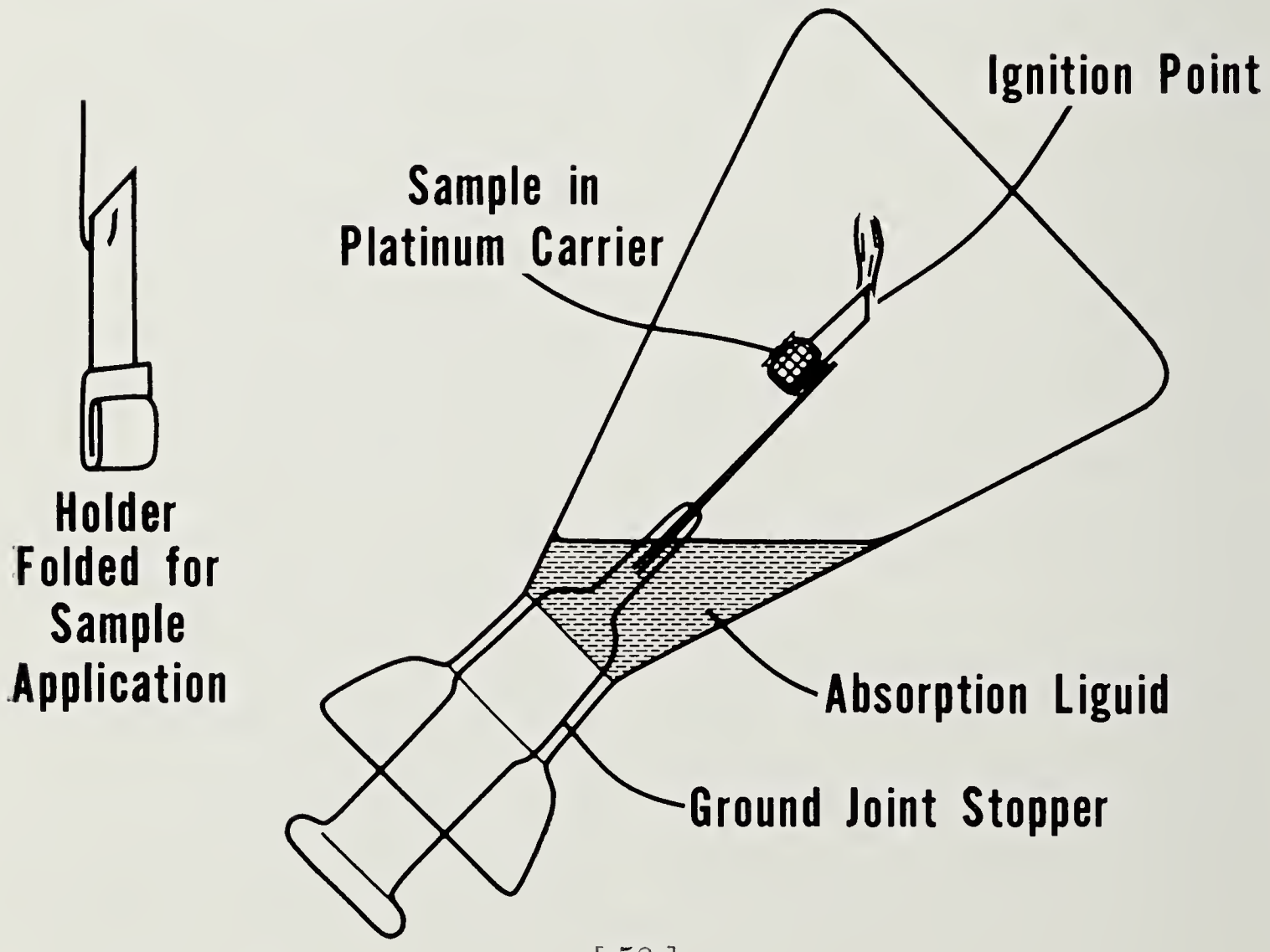
ABSTRACT.—A simple procedure is described for the analysis of solutions for sulfur and halogen content by the oxygen flask method. The method gives an average recovery of 100.32% with a standard deviation of 1.376 for 22 sulfur determinations on solutions of S-benzylthiuronium chloride. Good results are also obtained on solutions of other knwn compounds, extracts from natural products, and of commercial preparations. Three compounds boiling below 200°C. gave low results.

In 1955, Schöniger reintroduced the use of the oxygen flask for decomposing organic material before analysis. He first described this flask as used in an analytical method for halogen (1955) and later extended its use to include analysis for sulfur (1956).

Either a 250- or 500-ml. Erlenmeyer flask is modified by a funnel-like extension of the top. The flask is fitted with a ground glass stopper shaped into a sample holder. The top of the holder extends above the flask to form a handle. A platinum net or basket is fused into the lower part of the holder (Fig. 1).

Figure 1. Apparatus used for the oxygen flask combustion method.



The sample to be analyzed is weighed onto a 1-inch square ashless filter paper that has a narrow wicklike extension of one side. The sample is wrapped in the paper and placed in the platinum net.

The flask is first charged with a suitable absorbing solution and then filled with oxygen. The paper wick is ignited, and the sample holder immediately thrust into the flask. When combustion is complete, the gases are dissolved by the absorbing solution, which is then analyzed.

The use of this oxygen flask has greatly simplified the method of analysis of organic compounds for elements such as sulfur or halogen. In 1961, MacDonald discussed absorption solutions and methods of analyzing these solutions for 13 elements.

Sulfur determinations by the oxygen flask method were statistically evaluated by Malissa and Machherndl (1962). The 18 compounds they studied varied in sulfur content from 10 to 55%. There was no significant relationship between the standard deviation and the sulfur content, or between the standard deviation and the nature of the sulfur bond.

Although Ma and Gutterson (1964) discuss in a review article a number of techniques and modifications of the oxygen flask method as applied to specialized analytical problems, we have found no reference to its application to organic substances in solution. Therefore, we are reporting a suitable method for analysis of solutions. We also report the accuracy and precision of our analytical results, possible uses of the method as modified, and some of its limitations.

Materials and Methods

The oxygen flask, sample holder, carrier paper, and pipettes are all available from almost any laboratory supply house. Gouverneur and Eerbeek (1962) describe a flask safety jacket which can be made from heavy metal gauze shaped into a cone and fitted into a solid metal base.

Purity of the compounds which were used in testing the procedures were established as follows: S-benzylthiuronium chloride, cystine, methionine, and lysine hydrochloride were pure compounds as indicated within the accuracy and precision of analysis for the elements present. 1-Allyl-2-thiourea was an Eastman white label compound. The inorganic compounds, H_2SO_4, NH_4SCN, and $Na_2S_2O_3$ $5H_2O$, were of reagent grade. The ethylene chlorohydrin and 3-bromo-1-propanol were indicated by analysis for halogen content to be of 90% purity. The aqueous solution of trichloroacetic acid used for analysis was made from Eastman white label product and the amount of trichloroacetic acid present measured by titration with standard base.

Samples of these compounds were accurately weighed and dissolved in a suitable volume of water or other solvent. A volumetric pipette was used for the 1-ml. samples, and micropipettes for volumes of less than 1 ml. The solutions were pipetted on to paper holders suspended from a rack by a small wire hook as shown in Figure 1. After air drying, the papers were wrapped in a second paper holder and, finally, were dried for at least 1 hour in a vacuum desiccator over P_2O_5 at 20-30 mm. The samples were burned as usual, and the flask contents analyzed for either sulfur or halogen by the methods of D. C. White (1961, 1962).

As a safety precaution, all volatile solvents must be completely removed from the flask before the next combustion. Also, when substances dissolved in organic solvents are analyzed, the solvent must be completely removed before ignition. Using these precautions, we have performed thousands of oxygen flask combustions without a single explosion. Nevertheless, we *always* carry out the combustion with the flask in the metal basket as an added safety measure.

Results and Discussion

The average sulfur or halogen values and the standard deviation from

analysis of solutions of eight compounds are shown in Table 1. Based on all 22 analyses of S-benzylthiuronium chloride for sulfur, the method gave an average recovery of 100.32% with a standard deviation of 1.376. The accuracy and precision are of the same order we normally obtain for routine microanalytical determinations, and are comparable to the accuracy and precision reported for oxygen flask methods for sulfur (Malissa and Machherndl, 1962).

Table 2 contains the results of analysis of some extracts and commercial products. These samples may suggest use of the method in control work, analysis of plant extracts, inspection of commercial products, or in research on natural products. No analytical balance is required for these determinations.

Table 3 indicates that the method is not applicable to the analysis of compounds of high volatility when the solvent is removed as described.

Aqueous solutions were quantitatively transferred from the pipette to the paper without difficulty. In some determinations with low-boiling organic solvents, such as acetone, the solute tended to crystallize on the tip of the pipette. This crystallization made quantitative transfer of the material difficult.

TABLE 1.—Compounds of Known Composition.

Compounds	No. of Detns.	Sample Size		Sulfur, %		
				Found		Expected
		ml.[1]	mg.	Av.	Standard Deviation	
S-Benzylthiuronium chloride	18	0.25	6–7	15.86	0.217	15.82
S-Benzylthiuronium chloride[2]	4	1.00	8.0	15.90	0.217	15.82
1-Allyl-2-thiourea	5	0.50	4.0	27.35	0.134	27.54
Cystine[3]	3	0.50	3.0	26.56	0.201	26.67
Methionine	5	0.50	6.8	21.39	0.136	21.45
NH_4SCN	6	0.50	2.5	39.98	1.043	40.45[4]
$Na_2S_2O_35H_2O$	4	0.50	5.0	24.60	0.285	25.04[4]
S-Benzylthiuronium chloride	6	0.25	6.5	17.04[5]	0.105[5]	17.49[5]
Lysine·HCl	4	0.50	5.0	19.17[5]	0.289[5]	19.41[5]

[1] Water solutions unless otherwise specified.
[2] Dissolved in 80% ethanol.
[3] Dissolved in 1 normal HCl.
[4] Expected value obtained by analysis of solid.
[5] Percent chlorine.

TABLE 2.—Extracts and Commercial Products.

Substance	No. of Detns.	Sulfur, mg./ml. Found Av.	Found Standard Deviation	Present
Aqueous plant extract	6	2.71	0.030	2.74[1]
$CHCl_3$ plant extract	6	0.470	0.010	.....
Sugar substitute	7	6.52	0.117	6.28[2]
Detergent	8	3.44	0.053	3.48[3]
2,4,5,-T[4] (brush killer)	6	3.65[5]	0.070	3.66[3,5]

[1] Determined by an independent method.
[2] Computed from manufacturer's concentration figure.
[3] Determined by analysis of solid material or concentrate.
[4] Dissolved in 1-1 pentane-hexane and benzene.
[5] Percent chlorine.

TABLE 3.—Boiling Point versus Recovery of Halogen or Sulfur.

Compound	B. P., °C.	Recovery, %
Ethylene chlorohydrin	128–130	0–1
3-Bromo-1-propanol	170–175	28–38
Trichloroacetic acid	196–197	65–88
Sulfuric acid	340 (decomp.)	98–102

ACKNOWLEDGMENTS

We are indebted to Dr. William F. Kwolek for statistical interpretations and to Mrs. Anita Dirks for technical assistance.

This paper was a contribution to the honorary Symposium for Nicholas D. Cheronis at the Annual Meeting of the Illinois State Academy of Science, Chemistry Section, Northern Illinois University, DeKalb, Illinois, April 23, 1965. The Northern Regional Research Laboratory is a laboratory of the Northern Agricultural Research Service, U.S. Department of Agriculture; the mention of firm names or trade products does not imply that they are endorsed or recommended by the Department of Agriculture over other firms or similar products not mentioned.

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Manuscript received August 14, 1965.

A FIRST ITERATE FOR ASSOCIATION CONSTANTS

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ABSTRACT.—A new initialization procedure for iterative spectroscopic determinations of association constants is derived. It is proven that this initialization is valid when the concentration of dimer greatly exceeds the concentration of monomer. Numerical results are presented to substantiate the derivation. The effects of numerical manipulations are discussed.

Keefer and Andrews (1952) have derived a spectrophotometric iteration method for the determination of concentration constants of charge transfer complexes. Musulin, et al., (1962) have discussed the convergence failure of the method after it had been specialized (de Maine, et al. (1957), (1960a)) to determine concentration constants of association reactions. The purpose of this paper is to consider what effect there is upon the choice of the first iterates if the system deviates but slightly from Beer's law (Prutton and Maron (1951), pp. 756, 758). Although convergence failure destroys the ultimate utility of the method, there are other methods, e.g., Non-linear Least Square Method (Scarborough, (1950) pp. 463-9), which demand a good initial guess of the unknowns. The present analysis leads, fortuitously, to an initial iterate of the concentration constant which may be useful under the assumptions of this derivation. Finally, numerical calculations are presented in order to verify the theory.

The system to be investigated is the simple dimerization

$$2A \rightleftarrows A_2 \qquad (1)$$

In order to specify the notation, the equations of the iteration scheme, as taken from Musulin, et al., (1962) are given in Equations (2) to (5).

$$\frac{C^2_a}{D_C} = \frac{2}{\epsilon_C}(2C_a - C) + \frac{1}{K\epsilon_C} \qquad (2)$$

$$C = \frac{4KC_a + 1 - \sqrt{8KC_a + 1}}{4K} \qquad (3)$$

$$\frac{D}{C_a - C} = K\epsilon_C (C_a - C) + \epsilon_M \qquad (4)$$

$$D_C = \tfrac{1}{2} C\epsilon_C \qquad (5)$$

where C_a is the total solute concentration in monomeric units, $\frac{1}{2}$ C is the equilibrium dimer concentration, K is the concentration constant for Equation (1), (insufficient information is available concerning activity coefficients to be able to write a thermodynamic equilibrium constant), D and D_C are the absorbances (optical densities) of the solution and the dimer, respectively, and ϵ_C and ϵ_M are

the molar absorptivities (extinction cofficients) of the dimer and monomer, respectively. In these equations as well as the succeeding material, it is assumed that measurements are made in cells of unit path length. Should this not be so, the actual molar absorptivity would have to be obtained from the calculated molar absorptivity thru division by the path length.

Beer's Law and Initialization

In the derivation of Equations (2) to (5), the assumption has been made that the total absorbance is the sum of the absorbances of the monomer and dimer (Musulin, et al. (1962)). This assumption is stated mathematically as

$$D = D_M + D_C \tag{6}$$

where D_M is the monomeric absorbance given by

$$D_M = (C_a - C)\ \epsilon_M \tag{7}$$

Then

$$D = (C_a - C)\ \epsilon_M + \tfrac{1}{2}\ \epsilon_C\ C \tag{8}$$

If no equilibrium existed, Equation (8) would reduce to a simple statement of Beer's law. Also, Foley, et al., (1964) have shown that low members of the homologous nitroparaffin series obey Beer's law even though they are thought to undergo the reaction described in Equation (1). In such a case, if two species did occur, the fortuitous adherence to Beer's law would be described by

$$D = \bar{\epsilon} C_a \tag{9}$$

where $\bar{\epsilon}$ is an average molar absorptivity. It is of particular interest to see what effect the actual or accidental adherence to Beer's law would have on the initial values of the iterates.

Equation (9) may be obtained from Equation (8) by assuming

$$C = \delta C_a \tag{10}$$

where δ is a temperature dependent proportionality constant. Direct substitution of Equation (10) into Equation (8) gives

$$D = [\epsilon_M + \delta\ (\tfrac{1}{2}\ \epsilon_C - \epsilon_M)]\ C_a \tag{11}$$

which shows that

$$\epsilon = \epsilon_M + \delta\ (\tfrac{1}{2}\ \epsilon_C - \epsilon_M) \tag{12}$$

It may be pointed out that the concentration constant, which is

$$K = \frac{\tfrac{1}{2}\ C}{(C_a - C)^2} \tag{13}$$

becomes

$$K = \frac{\delta}{2C_a\ (1-\delta)^2} \tag{14}$$

under the assumption of Equation (10). Further, the special cases of the system containing all dimer or all monomer follow immediately from Equation (10).

If the system contains no dimer, C = O; and this is equivalent to assuming $\delta = 0$. Then

$$\begin{aligned} &\lim_{\delta \to 0} \quad D = \epsilon_M\ C_a \\ &\lim_{\delta \to 0} \quad K = 0 \end{aligned} \tag{15}$$

Equations (15) are precisely the description of a system containing all monomer.

If

$$\delta = 1 - \eta \tag{16}$$

where η is a constant, then the system containing all dimer is described by the assumption that $\eta = 0$. For then

$$\begin{aligned} &\lim_{\eta \to 0} \quad D = \tfrac{1}{2}\ \epsilon_C\ C_a \\ &\lim_{\eta \to 0} \quad K = \infty \end{aligned} \tag{17}$$

which is the description of a system containing all dimer.

Returning to the general problem, it is of interest to form the ratio, D/D_C.

$$\frac{D}{D_C} = \frac{[\epsilon_M + \delta\ (\tfrac{1}{2}\ \epsilon_C - \epsilon_M)]\ C_a}{\tfrac{1}{2}\ \epsilon_C\ C_a\ \delta} \tag{18}$$

or

$$\frac{D}{D_C} = 1 + \frac{2\epsilon_M}{\epsilon_C}\left(\frac{1}{\delta} - 1\right) \tag{19}$$

The starting point of the iteration scheme (Musulin, et. al. (1962)) is usuly made by assuming in Equation (2) that

$$D_C \cong D \tag{20a}$$

$$C \cong O \tag{20b}$$

However, from Equations (10) and (19), it is possible to substitute directly for

C and $1/D_C$ in Equation (2). After rearranging terms, one obtains

$$\frac{C_a^2}{D} = \frac{(2-\delta)\,C_a}{(\frac{1}{2})\,\epsilon_C + \epsilon_M\left(\frac{1}{\delta}-1\right)} + \frac{1}{K\left[\epsilon_C + 2\epsilon_M\left(\frac{1}{\delta}-1\right)\right]} \qquad (21)$$

Then, using Equation (12), Equation (21) becomes

$$\frac{C_a^2}{D} = \frac{(2-\delta)\,C_a}{\frac{1}{\delta}-\bar{\epsilon}} + \frac{1}{\frac{2}{\delta}-\bar{\epsilon}K} \qquad (22)$$

or

$$\frac{C_a^2}{D} = \frac{(2-\delta)\,\delta\,C_a}{\bar{\epsilon}} + \frac{\delta}{2\bar{\epsilon}K} \qquad (23)$$

Equation (23) represents a straight line if one plots C_a^2/D *vs.* C_a. The slope, m, and the intercept, b, of the straight line are given by

$$m = \frac{(2-\delta)\,\delta}{\bar{\epsilon}} \qquad (24)$$

$$b = \frac{\delta}{2\bar{\epsilon}K} \qquad (25)$$

Equation (24) is a quadratic equation in δ with the solution

$$\delta = 1^{\pm}\sqrt{1-m\bar{\epsilon}} \qquad (26)$$

Only the negative sign has physical significance since C cannot be greater than C_a.

Therefore, it is possible, if the system nearly obeys Beer's law, to obtain an estimate, $K^{(1)}$, for K. This information alone is insufficient to continue the iteration procedure since to return to Equation (2) one needs D_C. Yet, Equations (5), (6), and (7) form a system of three equations in four unknowns giving a singly infinite set of values for D_C. Clearly, some further information would be necessary to select the proper value of D_C.

Limitation of the Use of Beer's Law

Equation (9) may be obtained from Equation (8) in other ways than by using Equation (10). The various means are given by choosing (i) C = 0, (ii) $C_a - C = 0$, and (iii) $\epsilon_C = 2\epsilon_M$. The assumption of Equation (10) is equivalent to being in the region of $C_a - C = 0$. This may be seen mathematically by insertion of Equation (9) in Equation (23). After substitution,

$$\frac{C_a}{\bar{\epsilon}} = \frac{(2-\delta)\,\delta}{\bar{\epsilon}}\,C_a + \frac{\delta}{2\epsilon K} \qquad (27)$$

Equation (27) is an identity which is satisfied only by the conditions, $\delta = 1$ and $K = \infty$. Consequently, $K^{(1)}$ found from the use of Equation (23) is only useful if $K >> 1$. For the case under discussion and for the starting point given by Equation (20), $K^{(1)}$ is found from plots of C_a^2/D *vs.* C_a. Without a true convergence scheme, one cannot be sure whether a $K^{(1)}$ from Equation (23) really describes the system or whether $K^{(1)}$ is determined simply by Equation (27).

The same conclusions are obtained without limiting the functional form as in Equation (8). For example, if the solution is nearly all dimer, one can let the monomer concentration be

$$C_a - C = \eta \qquad (28)$$

where η is a small quantity which vanishes in the limit. Now as before, the quotient D/D_C is formed.

$$\frac{D}{D_C} = 1 + \frac{2\eta\epsilon_M}{\epsilon_C\,(C_a-\eta)} \qquad (29)$$

Again, $1/D_C$ from Equation (29) and $(2\,C_a - C)$ derived from Equation (28) are substituted into Equation (2) yielding

$$\frac{C_a^2}{D}\left[1 + \frac{2\eta\epsilon_M}{\epsilon_C\,(C_a-\eta)}\right] = \frac{2}{\epsilon_C}(C_a+\eta) + \frac{1}{\epsilon_C K} \qquad (30)$$

If $\eta \rightarrow 0$ in Equation (30), one obtains a straight line plot of C^2_a/D *vs.* C_a with slope, m, and intercept, b, given by

$$m = \frac{2}{\epsilon_C} \qquad b = \frac{1}{K\epsilon_C} \tag{31}$$

It should be noted that the starting assumptions, Equations (20), which had been used, heretofore, are contradictory in that Equation (20a) implies all dimer and Equation (20b) implies all monomer. By putting these conditions into Equation (2), the first iterates can be compared to those obtained by the condition given in Equation (28). (The subscript refers to the equation giving rise to the iterate).

$$\epsilon^{(1)}_{28} = \tfrac{1}{2}\,\epsilon^{(1)}_{20} \qquad K^{(1)}_{28} = K^{(1)}_{20} \tag{32}$$

Consequently, one would obtain the same $K^{(1)}$ but again, with either starting assumption, reasoning similar to that used to obtain Equation (27) shows that $K>>1$.

Numerical Results

Several calculations were performed in order to ascertain if the conclusions reached analytically would be verified with typical data. The majority of the data were those from the nitroparaffin study of Foley, et al. (1964). However, several other experiments were used in order to broaden the base upon which the conclusions are based. The details of the various experimental procedures may be found in the original papers. The calculations were performed upon an IBM 1620 computer. All programs were written in FORTRAN II.

Equation (23) is derived under the assumption that two solute species coexisted in such a manner that the absorbance of the solution obeyed Beer's Law. Consequently, one would expect that plots of C^2_a/D *vs.* C_a become more linear as plots of D *vs.* C_a become more linear. Since Foley, et al., (1964) have shown that Pearson's Correlation Coefficient is a good means of determining linearity from chemical data, the same technique was used to test these plots. The correlation coefficients, r_1 and r_2, were calculated at each wave length for plots of D *vs.* C_a and $C^2_a/4D$ *vs.* $2C_a$, respectively. Although the latter involves a change of scaling (thought to be necessary in originating the investigation), the scaling does not alter the computation of r_1 and r_2. These values were averaged over all wave lengths involving the same concentration values to give the average correlation coefficients, $\bar{r}_1$ and $\bar{r}_2$. The average correlation values are tabulated in Table 1 along with quantities defining the specific experiments.

Table 1 clearly indicates that Equation (23) is linear if the system obeys Beer's Law. As long as the system nearly obeys Beer's Law, there is a direct proportionality between the two correlation averages. However, if the data deviates widely from Beer's Law (and this means only a value of $r < .995$) (Foley, et. al. (1964)), then Equation (23) shows essentially no linearity, e.g., consider the first two entries of $C_2H_5NO_2$. It should be noted that certain data which are known to be experimentally poor have been included in order to extend the range of the calculations. This has been done using the hypothesis that a

TABLE 1.—Averaged Pearson Correlation Coefficients of Various Binary Solutions for Different Concentration Ranges.

Solute	Solvent	Concentration Range (10^2 M)	$\bar{r}_1$	$\bar{r}_2$
CH_3NO_2	CCl_4	0.6 - 3.0	.99471	.99501
		1.0 - 3.0	.99836	.99851
		1.5 - 3.0	.99982	.99981
		10. - 25.	.99939	.99946
		1.0 - 5.0	.99902	.99896
		6.58 - 1864	.97866[a]	.98377[a]
	H_2O	1.0 - 5.0	.99538	.99447
$C_2H_5NO_2$	CCl_4	0.8 - 3.0	.94468	.60541
		1.0 - 5.0	.97460	.76778
		1.0 - 3.0	.99948	.99947
		1.0 - 5.0	.99673	.99481
	H_2O	1.0 - 5.0	.99820	.99714
1-$C_3H_7NO_2$	CCl_4	1.25 - 3.0	.96614	.98626
		12.5 - 30.	.99761	.99666
2-$C_3H_7NO_2$[b]	CCl_4	1.25 - 3.0	.99755	.99813
		12.5 - 30.	.99883	.99919
2,5-dimethylpyrazine[c]	25% H_2SO_4	.002 - .01	.99998	.99998
2-methylpyrazine[c]	H_2O	.002 - .01	.99613	.99507
Pyrazine[c]	75% H_2SO_4	.002 - .01	.99995	.99995
Cyclohexanol[d]	CCl_4	0.10 - 5.65	.98854	.99338
CH_3NO_2[e]	CCl_4	38 - 1851 (3.29 μ)	.98952	.97332
CH_3NO_2[e]	CCl_4	38 - 1851 (3.42 μ)	.99823	.99734

[a]Pestemer and Fruhwirth (1937). [b]From rounded data. [c]Chia (1960).
[d]Masschelein (1962). [e]de Maine (1960b).

computer would not differentiate between deviations originating from chemical interaction and those from an inexperienced experimenter.

The foregoing supports previous experimental work that plots of C^2_a/D *vs.* 2 C_a were linear in the range where Beer's Law was obeyed to within two per cent (de Maine, et. al. (1960a)).

Under the assumption that the solution obeys Beer's Law (or nearly so), it has been proposed (follow Equation (27)) that $K >> 1$. However, if this is so, serious computational difficulties must occur. If $K >> 1$, then the intercept, b, of Equation (27) must approach zero. This in fact does occur in this investigation for $b \sim 0(10^{-5})$. Unfortunately, if b is this order of magnitude, a slight experimental error could cause a value of $b < 0$. Again, it may also be stated that as $b \to 0$, one would expect random fluctuations about the limiting value which would also give rise to values of $b < 0$.

A negative value of b results in a physically unreal value of $K^{(1)}$. Nevertheless, in the present work the average value of the first iterate, $K^{(1)}$, including any negative values which may occur, is calculated. Now two questions must be answered. Firstly, is the value of $\overline{K}^{(1)}$ reasonable? Reasonability could be ascertained by a possible correlation of $\overline{K}^{(1)}$ values of different homologues and/or the correlation of $\overline{K}^{(1)}$ values

in different solvents. Secondly, regardless of the value of $\overline{K}^{(1)}$, is it true that $\overline{K}^{(1)}$ is independent of wave length? The answer to the latter question is aided by the calculation of the per cent deviation (% Deviation = $(\overline{K}^{(1)} - \overline{K}^{(1)}/K^{(1)}) \times 100$). The pertinent quantities are given in Table 2.

It is clear from Table 2 that no pattern emerges from the $\overline{K}^{(1)}$ values except chaos. Some physically unreal values occur; some large values occur; and some small values, resulting from the fortuitous cancellation of positive and negative values, occur.

In no case does $\overline{K}^{(1)}$ show a functional dependence upon wave length. On the other hand, there is usually great randomness, as indicated by the large values of the average deviations. A close comparison of the values of per cent deviation and the values of $\bar{r}_1$ leads to the conclusion that as Beer's Law becomes more completely satisfied by the absorbances of the solution, the calculated values of $K^{(1)}$ become more random. In fact, only the very poor data of $C_2H_5NO_2$ ($\bar{r}_1 = .94468$), (later shown to be erroneous by remeasurement), and the questionable 1-$C_3H_7NO_2$ data ($\bar{r} = .96614$) showed any lack of randomness in the $\overline{K}^{(1)}$ values. It appears that once Beer's Law is obeyed, or nearly so ($\bar{r}_1 \geqq .995$), the amount of deviation is completely random.

The cancellation of positive and negative values of $K^{(1)}$ in obtaining $\overline{K}^{(1)}$ may be avoided by calculating the average, $|\overline{K}^{(1)}|$, of the absolute values of $K^{(1)}$. Then one would expect either that $|\overline{K}^{(1)}| >> 1$ or that $K >> 1$. The former resulted upon division by a value of $b << 1$. The latter was proven, by analysis, to result from Equation (27). This becomes more true as the plot of C^2_a/D *vs.* C_a approaches linearity (as measured by $\bar{r}_2$). The values of $|\overline{K}^{(1)}|$ are given in Table 3.

TABLE 2.—The Averaged First Iterate of each Concentration Constant for Various Binary Solutions.

Solute	Solvent	Concentration Range (10^2 M)	$\overline{K}^{(1)}$ *l*/mole	Deviation (%)	$\bar{r}_1$
CH_3NO_2	CCl_4	0.6 - 3.0	781	58	.99471
		1.0 - 3.0	—254	48	.99842
		1.5 - 3.0	267	30	.99982
		10. - 25.	—176	52	.99939
		1.0 - 5.0	764	61	.99902
	H_2O	1.0 - 5.0	338	187	.99538
$C_2H_5NO_2$	CCl_4	0.8 - 3.0	11	2	.94468
		1.0 - 5.0	11	. .[b]	.97460
		1.0 - 3.0	2460	120	.99948
		1.0 - 5.0	149	97	.99673
	H_2O	1.0 - 5.0	716	113	.99820
1-$C_3H_7NO_2$	CCl_4	1.2 - 3.0	—93	15	.96614
		12. - 30.	—42	46	.99761
2-$C_3H_7NO^a{}_2$	CCl_4	1.2 - 3.0	—377	54	.99755
		12. - 30.	—38	34	.99883

[a]Rounded data.
[b]Single reading, thus no deviation.

An inspection of the values in Table 3 shows that, in general, $K^{(1)} >> 1$ for values of $\bar{r}_2 > 0.995$. The decision as to largeness is based upon the fact that values of $K \sim 100$ correspond to approximately 90% dimer. Further, a comparison of the values of $|\overline{K}^{(1)}|$ and $\bar{r}_2$ leads to the same conclusions that are deduced from Table 2.

Numerical Experimentation

In any practical analysis where numerical work enters the border regions of limiting validity, it behooves one to carry forth numerical experimentation to eliminate any possible numerical influences upon the conclusions. Several such experiments have been carried out in connection with the present investigation.

For several of the solutions, error limits were assigned to the measured concentration values (Foley, et. al. (1964)). All quantities were calculated with concentrations given to four significant figures, concentrations with the assigned error added (to four significant figures), concentrations with the assigned error subtracted (to four significant figures), and finally the concentrations rounded to the values assigned in Tables 1 to 3 to the column designated Concentration Range. The median values (uncorrected four figure values) were used, except as noted, to calculate the quantities in Tables 1 to 3.

Table 4 tabulates the effect of the various numerical changes upon the pertinent quantities for some sample nitromethane and nitroethane solutions. These selections represent the typical behavior which was found.

The most startling fact shown in Table 4 is that, if the solution obeys Beer's Law (or nearly so), the calculation of $K^{(1)}$ is extremely sensitive to the error in the dependent variable and even more so, if possible, to the number of significant figures retained. Since the errors involved are of the order of 1 to 2%, a twenty-five per cent change in $K^{(1)}$ is unreasonable. Foley, et

Table 3.—The Averaged Absolute Value of the First Iterate of each Concentration Constant for Various Binary Solutions.

Solute	Solvent	Concentration Range (10^2 M)	$\lvert\overline{K}^{(1)}\rvert$ *l*/mole	$\bar{r}_2$
CH_3NO^2	CCl_4	0.6 - 3.0	945	.99501
		1.0 - 3.0	327	.99859
		1.5 - 3.0	320	.99981
		10. - 25.	176	.99946
		1.0 - 5.0	801	.99896
	H_2O	1.0 - 5.0	676	.99447
$C_2H_5NO_2$	CCl_4	0.8 - 3.0	11	.60541
		1.0 - 5.0	11	.76778
		1.0 - 3.0	2456	.99947
		1.0 - 5.0	181	.99481
	H_2O	1.0 - 5.0	986	.99714
1-$C_3H_7NO_2$	CCl_4	1.2 - 3.0	93	.98626
		12. - 30.	48	.99666
2-$C_3H_7NO_2$[a]	CCl_4	1.2 - 3.0	397	.99813
		12. - 30.	38	.99919

[a]Rounded data.

TABLE 4.—The Effect of Experimental Error Upon Pertinent Calculated Quantities for Selected Binary Solutions.

Solute	Solvent	Concentration Manipulation	$\lvert\bar{K}^{(1)}\rvert$ *l*/mole	$\bar{K}^{(1)}$ *l*/mole	Deviation (%)	$\bar{r}_1$	$\bar{r}_2$
CH_3NO_2	CCl_4	Rounded	1523	1399	63	.99388	.99454
		Error Added	773	586	63	.99472	.99499
		Median	945	782	58	.99471	.99501
		Error Subtracted	922	741	63	.99487	.99517
CH_3NO_2	CCl_4	Rounded	2180	1340	183	.99990	.99990
		Error Added	199	120	107	.99944	.99941
		Median	320	267	31	.99982	.99981
		Error Subtracted	419	384	56	.99987	.99987
$C_2H_5NO_2$	CCl_4	Rounded	11	11	2	.94699	.60437
		Error Added	11	11	2	.94504	.60502
		Median	11	11	2	.94468	.60541
		Error Subtracted	12	12	2	.94357	.60131

al., (1964) point out that the same sensitiveness does not occur in the calculation of the molar absorptivities. The present numerical experimentation has focused upon the $K^{(1)}$ values since the analysis has proven that they, not $\epsilon c^{(1)}$ would be the most sensitive. On the other hand, if deviations from Beer's Law occur, Table 4 clearly shows the insensitiveness of $K^{(1)}$.

If $K^{(1)} >> 1$ (here the largeness is a true numerical largeness, $\sim 0(10^3)$, not a physically significant largeness, $\sim 0(10^2)$), the per cent deviation remains essentially constant even if the system obeys Beer's Law. However, if $K^{(1)} > 1$, then the denominator in the calculation of per cent deviation does not provide sufficient stability to keep that quantity constant.

Finally the correlation coefficients remain essentially constant under all changes in the dependent variable. This reflects the usefulness of the correlation coefficient (if one is careful in its use) in chemical and physical problems (Gottschalk, (1962)). Alternatively, one could say that the degree of "fit" to Beer's Law is invariant within experimental error.

In the original investigation, several chemical experiments were attempted in order to fix variables. In light of the preceding conclusions these, too, must be reduced to numerical experimentation. That is, no chemical information was found but more is learned concerning the numerical framework.

For example, in one experiment two different sets of solutions, the members of which contained the same concentrations to within experimental reproducibility, were made. In another experiment the same solution was measured, spectrophotometrically, three or four days later. The pertinent quantities were calculated for each of these cases and representative values given in Table 5.

The pattern is the same as before. For example two solutions of $C_2H_5NO_2$, having essentially the same degree of "fit" to Beer's Law, measured on the initial day of preparation, gave widely divergent

TABLE 5.—The Behavior of Pertinent Calculated Quantities for Selected Binary Solutions as a Function of Attempts at Chemical Reproducibility.

Solute	Solvent	Solution No.	Day of Measurement	$\lvert\overline{K}^{(1)}\rvert$ l/mole	$\overline{K}^{(1)}$ l/mole	Deviation (%)	$\overline{r}_1$	$\overline{r}_2$
CH_3NO_2	H_2O	1	1	676	338	187	.99538	.99447
	H_2O	2	1	861	—138	670	.99678	.99524
	H_2O	1	4	3800	—430	856	.99821	.99816
$C_2H_5NO_2$	H_2O	1	1	986	716	113	.99820	.99714
	H_2O	2	1	1410	80	1705	.99794	.99821
	H_2O	1	3	1490	—187	769	.99248	.98992

values of $K^{(1)}$ as shown by the average values. The correlation coefficients show some information of the nature of the chemistry; but, these, as usual, bear no relation to $K^{(1)}$ values.

Conclusion

The above results clearly show that, with the first iterate $K^{(1)}$, obtained from the iteration process given by de Maine, et al., (1957, 1960a), one cannot obtain a valid estimate of an association constant, K, if the chemical system obeys Beer's Law, (or nearly so). That is, if the deviations from Beer's Law are small, then there appears a complete randomness in the values of $K^{(1)}$.

On the other hand, the mathematical proof given in this paper shows that the starting point of the iterative procedure given by de Maine, et al., (1957, 1960a) is formally equivalent to an equation derived for a chemical system nearly obeying Beer's Law as a result of being composed almost entirely of dimer. Since a system which is nearly all dimer has a very large association constant ($K >> 1$), any value of $K^{(1)}$ which is small ($K^{(1)} < 1$) or large ($K^{(1)} > 1$) is questionable.

Since the binary solutions of nitroparaffins obey Beer's Law in the concentration ranges studied (Foley, et al., (1964)) the iteration process given by de Maine, et al., (1957, 1960a) does not give an interpretable value of $K^{(1)}$ because of randomness. It is possible that some chemical system exists which deviates significantly enough from Beer's Law to give a non-random value of $K^{(1)}$. However, since one could not iterate this value to a constant value (Musulin, et al., (1962)), and since the value is obtained from an equation which has no rigorous mathematical validity, the non-random $K^{(1)}$ could not be ascribed any reliability. Hence, one must conclude that the iterative procedure given by de Maine, et al., (1957, 1960a) has no practical value.

Acknowledgment

The author is grateful for support of the Petroleum Research Fund (Grant 602-B) administered by the American Chemical Society during a portion of this investigation. He also wishes to thank the Computing Center of Southern Illinois University for the use of the IBM 1620 and the necessary ac-

cessory equipment and supplies. Thanks are accorded Prof. W. Byers Brown for helpful discussion.

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Manuscript received February 6, 1965.

THE SOLUBILITY OF BARIUM MONOFLUOROPHOSPHATE

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ABSTRACT.—The solubility of barium monofluorophosphate, $BaPO_3F$, in water at 25°C has been determined to be (7.7 ± 0.6) X 10^{-4} g-moles/liter. Mean activity coefficients of $BaPO_3F$, as a function of ionic strength, approach the limiting Debye-Huckel slope for a 2-1 electrolyte.

For the sparingly soluble salt, $BaPO_3F$, the following equilibium equation applies:

$$BaPO_3F_{(s)} = Ba^{+2} + PO_3F^{=} \quad (1)$$

The solubility product constant is expressed as

$$K_{SP} = a_{Ba}{}^{+2}\ a_{PO3F}{}^{=} \quad (2)$$

where K_{SP} is the thermodynamic solubility product constant of the salt.

Equation (2) may be rewritten as:

$$K_{SP} = c_{Ba}{}^{+2}\ c_{PO_3F}{}^{=} \cdot \gamma_{Ba}{}^{+2}{}_{PO_3F}{}^{=} \quad (3)$$

where c_{Ba+2} and $c_{PO_3F}{}^{=}$ represent the molarities of the ions and γ the respective ionic activity coefficients.

Allowing

$$K_{SP} = c_{Ba}{}^{H}\ c_{POF}{}^{=} \quad (4)$$

$$\gamma^2{}_{\pm} = \gamma_{Ba}{}^{+2}\ \gamma_{PO_3F}{}^{=} \quad (5)$$

where $K_{SP'}$ is the concentration solubility product and $\gamma_{\pm}$ is the mean activity coefficient of $BaPO_3F$, then from (3)

$$K_{SP} = K_{SP'}\ \gamma^2{}_{\pm} \quad (6)$$

Since $\gamma_{\pm}$ is dependent on the ionic strength of the solution, $K_{SP'}$ must vary as ionic strength varies. From (4)

$$K_{SP'} = S^2 \quad (7)$$

where S is the solubility of the salt. So,

$$K_{SP} = S^2\gamma^2{}_{\pm} \quad (8)$$

The Debye-Huckel Theory predicts that the activity coefficients of solutions of electrolytes decrease as ionic strength increases in dilute solutions, hence one would expect an increase in solubility of the salt as the ionic strength of the solution is increased by the addition of an inert electrolyte.

The thermodynamic solubility product constant is independent of the ionic strength of the solution so that we may write the equation:

$$K_{SP} = S^2\gamma^2{}_{\pm} = S_o{}^2\ \gamma_o{}^2 \quad (9)$$

where S and $\gamma_{\pm}$ are for solutions of a certain ionic strength and S_o and γ_o are for a solution of zero ionic strength. Taking the square root of equation (9) and the logarithm of that equation; we obtain the result

$$\log S = \log S_o\gamma_o - \log \gamma_{\pm} \quad (10)$$

In this linear equation, $\log S_o\gamma_o$ is a constant and $\log \gamma_{\pm}$ is linearly

dependent on the square root of the ionic strength, μ, by virtue of the Debye-Huckel limiting law. Therefore, a plot of log S against $\sqrt{\mu}$ should be linear, the intercept at $\mu = 0$ yielding the true thermodynamic solubility product, K_{SP}. The slope of the line should be such that, as the square root of the ionic strength increases, log S should increase. The mean activity coefficients of $BaPO_3F$ in solutions may be calculated from (10).

Procedures

$BaPO_3F$ was prepared by adding 0.5 molar Na_2PO_3F to 0.5 molar $BaCl_2$. The resulting precipitate of $BaPO_3F$ was washed and dried to constant weight over $CaCl_2$. The salt was analyzed for total barium (Pierce, Haenisch and Sawyer, 1958) and total fluoride (Armstrong, 1933). These analyses established a 95% purity for the $BaPO_3F$ with barium ortho- and meta-phosphates as the probable impurities.

A stock solution of potassium chloride was prepared by weight from Analytical Reagent grade KCl oven-dried at 110°C. A stock solution of magnesium chloride was prepared from reagent-grade $MgCl_2 \cdot 6H_2O$ and analyzed for chloride ion by the Mohr method.

A series of KCl and $MgCl_2$ solutions of varying ionic strengths were prepared by dilution of the stock solutions. Each of these solutions was saturated with $BaPO_3F$ by adding solid $BaPO_3F$ to the solution and heating to 35°C for 15 minutes. The solutions were then allowed to equilibrate at 25.00 ± 0.02°C in an oil bath.

About 15 ml of the saturated supernatant liquid was separated by filtration and acidified with 5 ml of 12 molar HCl. The acidified solution was heated on a steam bath for 15 minutes to hydrolyze the monofluorophosphate to orthophosphate and fluoride ions (Lange, 1950) and the resulting solution analyzed for orthophosphate by the spectrophotometric molybdo-vanadate method (Quinlan and DeSea, 1955). The concentration of $BaPO_3F$ was then calculated directly from the orthophosphate concentration.

Results

Table 1 summarizes the data for the solubility, S, in moles per liter and the mean activity coefficient, $\gamma_\pm$, of $BaPO_3F$ as a function of ionic strength in solutions of $MgCl_2$ and KCl. A plot of –log S vs $\sqrt{\mu}$ yields a straight line as predicted by the Debye-Huckel limiting law. Least-squares analysis of the data for KCl and $MgCl_2$ solutions give the limiting values of –log S_o of 3.109 ± 0.034 and 3.117 ± 0.035 respectively. Averaging these values gives a value of $S_o = (7.7 \pm 0.6) \times 10^{-4}$ g-moles/liter. This compares favorably with the value of 6×10^{-4} at 20°C determined by Lange (1950).

In Figure 1 we have plotted the calculated values of log $\gamma_\pm$ of $BaPO_3F$ versus $\sqrt{\mu}$ in KCl and

Table 1.—Solubilities and Mean Activity Coefficients of $BaPO_3F$.

In Solutions of KCl		
$\sqrt{\mu}$	—log S	$\gamma_\pm$
0.6810	2.68	0.38
0.4832	2.73	0.43
0.3431	2.93	0.68
0.2221	2.96	0.73
0.1638	2.99	0.78
0.1485	2.99	0.78
0.1125	3.04	0.87
0.08418	3.06	0.91
0.2009	2.96	0.73
In Solutions of $MgCl_2$		
$\sqrt{\mu}$	—log S	$\gamma_\pm$
0.7736	2.53	0.27
0.5504	2.63	0.34
0.3521	2.77	0.47
0.2518	2.93	0.68
0.1637	3.03	0.85
0.2283	2.88	0.60
0.1140	3.04	0.87
0.08949	3.07	0.93
0.2763	2.84	0.55
0.3170	2.78	0.48

$MgCl_2$ solutions. It can be seen that the data very nearly approximate the behavior of a 2-1 electrolyte rather than a 2-2 electrolyte as one might expect at first consideration. The lines on the graph represent the limiting form of the Debye-Huckel equation for the dependence of the mean activity coefficient upon the ionic strength of a solution. The expression for the Debye-Huckel equation is:

$$\log \gamma_{\pm} = -A\, Z_+ Z_- \sqrt{\mu} \qquad (11)$$

where A is a constant dependent upon type of solvent and temperature and has the value 0.509 for water at 25°C and Z_+Z_- represents the charge of the cation and anion of the electrolyte in question.

The observed behavior of $BaPO_3F$ as a 2-1 electrolyte is readily explained. The second dissociation constant of monofluorophosphoric acid, H_2PO_3F, has a value of 1.2×10^{-5} (Bruns, 1963). In solutions of such low concentration of $PO_3F^=$ as are encountered in this study, the hydrolysis of the ion to form HPO_3F^-, because of the weakly acidic nature of the second hydrogen ion, is nearly complete, that is to say

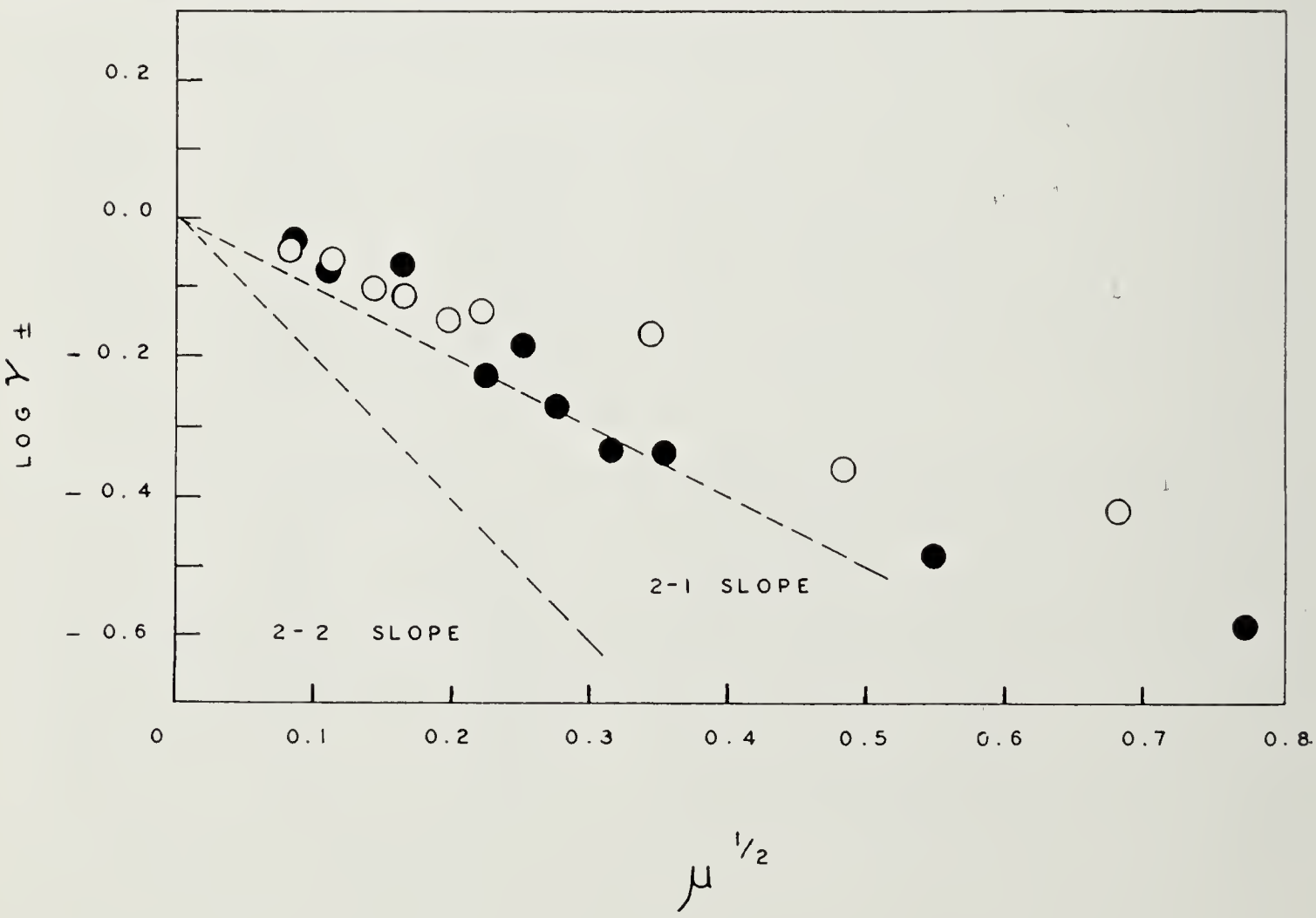
$$PO_3F^= + H_2O \rightarrow HPO_3F^- + OH^- \qquad (12)$$

Hence the physical properties of aqueous solutions would, indeed be expected to approximate those of an electrolyte with a doubly charged cation and singly charged anion.

Acknowledgment

This work was supported in part by a grant from the Research Corporation. The sodium monofluorophosphate was a gift from Ozark-Mahoning Co., Tulsa, Oklahoma.

Figure 1.—Mean activity coefficients vs. $\sqrt{\mu}$ for $BaPO_3F$ in aqueous solutions of KCl (open circles) and $MgCl_2$ (filled circles).



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Manuscript received February 4, 1965.

NEWS AND COMMENTS

The time has come to reproduce the Figure 1 showing what a typed manuscript should look like. We have a lot of new members that have never seen this illustration.

Professor Stanley Harris sent me a note stating that "The Illinois Academy of Science has a small sum available to support research work. The A.A.A.S. contributes funds for this purpose on a per member basis. Some of us think that the Academy might at least match this sum. We might especially urge scientists from the smaller schools to apply to the Academy for support."

All my "news" seems to come from Southern. I wish I could "nag" each of you in person as I do the local members in order to get information.

"The Department of Botany at Southern Illinois University has announced the addition of two faculty members for 1965-66.

Mr. William H. Eshbaugh, Assistant Professor, joined the department's staff in December, following his release from active military service at Dugway Proving Ground, Dugway, Utah, where he has been engaged in research. Mr. Eshbaugh received his doctorate from Indiana University in 1964. His particular interests are plant taxonomy, biosystematics and plant geography. He has assumed major responsibility as curator of the University Herbarium.

Mr. Lawrence Matten, Assistant Professor, was formerly an instructor at State University of New York. He was granted his Ph.D. by Cornell University in 1965. He is especially interested in plant anatomy, plant morphology, and paleobotany.

In addition to its regular program of field work the Illinois State Museum pursued two archaeological projects in 1965 which were financed by research grants and contracts. In April and May the Museum conducted an archaeological survey of future Oakley Reservoir near Decatur under a $2500 contract with the National Park Service. In October a survey was begun of a new 6,000-acre steel mill site near Hennepin, Illinois, under a grant of $2775 from the Jones & Laughlin Steel Corporation of Pittsburgh. In each case the funds were received and administered by the Illinois State Museum Society for the Museum. Dr. Joseph R. Caldwell, Head Curator of Anthropology, Illinois State Museum, was project director of the Oakley survey and Dr. C. G. Holland, University of Virginia, field supervisor. Dr. Robert L. Hall, Curator of Anthropology, Illinois State Museum, is project director of the Hennepin survey and James P. Anderson, University of Illinois, field supervisor.

Boris Musulin is not my favorite author. Having four of his papers in this issue came about as a result of "production problems" whereby we had to hold several "chemistry" papers, originally scheduled for earlier issues, in galley until now.

Figure 1.—A sample page showing how to type a manuscript for the Transactions.

A GUIDE FOR TYPING MANUSCRIPTS FOR

ILLINOIS ACADEMY OF SCIENCE PUBLICATIONS

EDWIN C. GALBREATH

Southern Illinois University, Carbondale

ABSTRACT.--This is the format for preparing manuscripts to be submitted to the Illinois Academy of Science.

Start here without more ado. Double space everything. Do not hyphenate words at the end of a line. Write out and capitalize the words Table and Figure every time. Each Table should be on a separate page with the legend in paragraph form and the principal words capitalized. Legends for figures should be in paragraph form and on a separate page. Center headings should be centered and in capital letters as in this example:

DISCUSSION

Authors' names should be in capital letters in the Literature Cited section. Side headings should be indented, principal words capitalized, and italicized thus:

The Use of Italics and Other Styles of Type. Mark other type styles, such as "bold face", with a light pencil.

LITERATURE CITED

APPLE, J., and W. MULE. 1929. Distilling made easy.

Printing Office. Chicago. 439pp.

NOTES

OCCURRENCE OF THE INTACT SPERMATOZOA IN SPONTANEOUS EJACULATIONS OF ISOLATED MALE GUINEA PIGS

JAN MARTAN
Southern Illinois University, Carbondale, Illinois

ABSTRACT.—Spermatozoa were observed in coagulated spontaneous ejaculates of isolated male guinea pigs. The spermatozoa were morphologically intact, mostly grouped in rouleaux and their acrosomes were PAS positive. Spontaneous ejaculation in a non-mating male may be a way of eliminating spermatozoa from the genital tract.

In the course of studies on mature male guinea pigs, coagulated ejaculates have been observed in the cage service pans. A review of the pertinent literature indicates that very little is known about the fate of spermatozoa which are not used in copulation (Bishop and Walton, 1960; Bishop, 1961; Mann, 1964). Although several theories have been suggested (Simeone and Young, 1931; Amann and Almquist, 1962), the processes and locations of spermatozoa breakdown and the methods of their elimination are unknown. Spontaneous ejaculations are not mentioned. Preliminary observations concerning this phenomenon are the subject of this report.

MATERIALS AND METHODS

Five adult male guinea pigs (6-12 months old) were caged individually and kept on a standard pellet diet, supplemented with hay, carrots and cabbage. For one week, service pans in their cages were paper-lined daily and inspected around 10 a.m. for coagulated ejaculates. Those found were fixed in 10% neutral formalin containing 1% cadmium chloride. Ejaculates were embedded in paraffin and sectioned at 8 μ. Feulgen or Azure B methods (Swift, 1955) were used to visualized deoxyribose nucleic acid in the nuclei of the spermatozoa. Acrosomes were localized by the PAS (periodic acid Schiff) reaction (Leblond and Clermont, 1952). The latter technique was also used in combination with hematoxylin, Azure B or Alcian blue methods (Mowry, 1956).

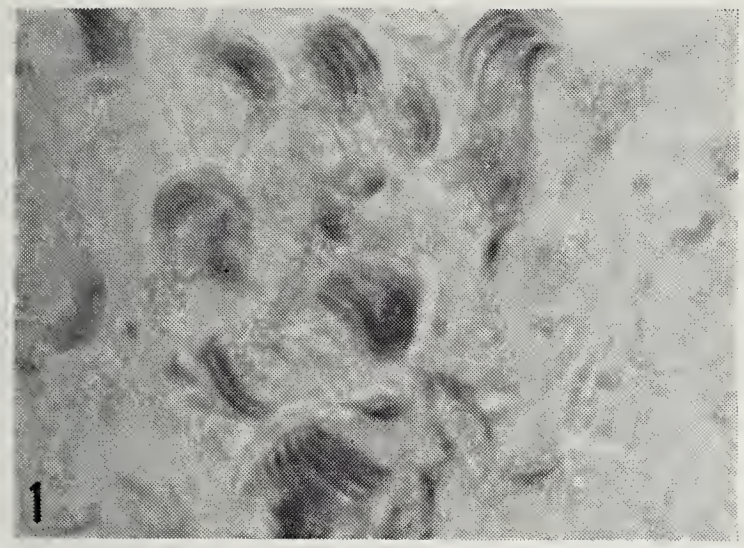
Epididymides and vasa deferentia from three adult guinea pig males (6-8 months old) were treated in the same manner as described for the ejaculates.

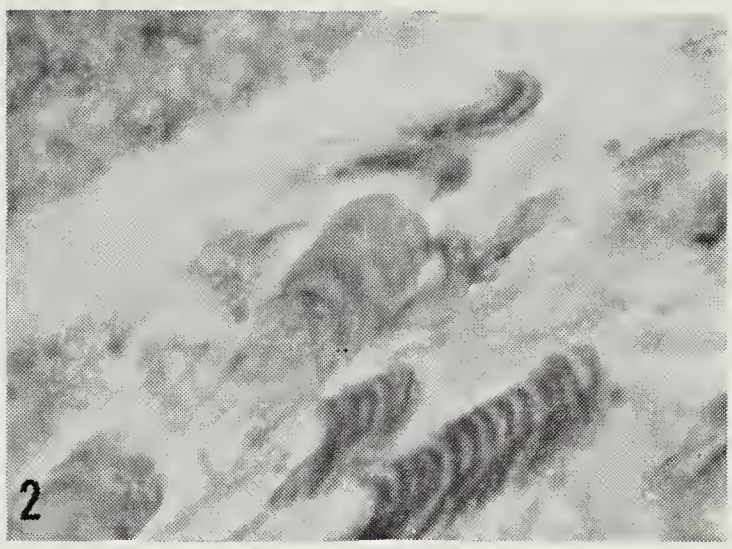
RESULTS

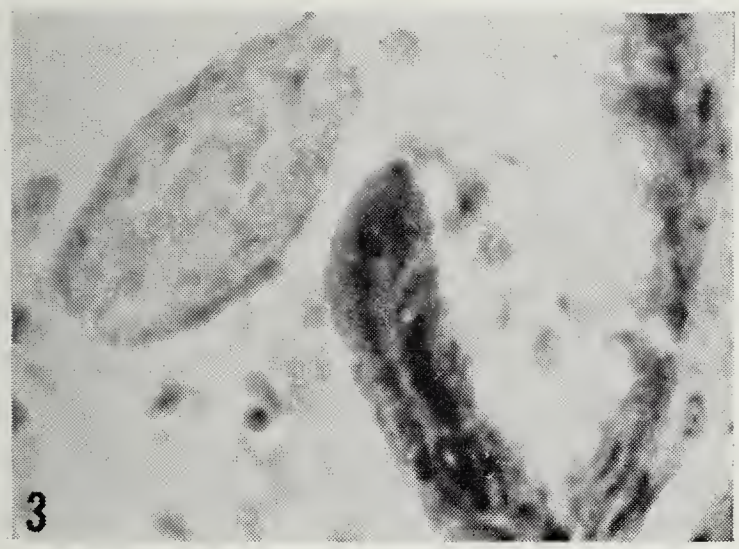
During the collecting week, 12 coagulated spontaneous ejaculates were found (range 2-3). All contained morphologically well preserved spermatozoa. The great majority of spermatozoa adhered to one another in tightly fitted groups with their bent heads in close contact (Fig. 1). Large crescent shaped acrosomes, characteristic of the guinea pig spermatozoa, were strongly positive with PAS technique (Fig. 1). In the all staining reactions performed, the spermatozoa in the spontaneous ejaculates did not differ from those inside the excurrent genital ducts.

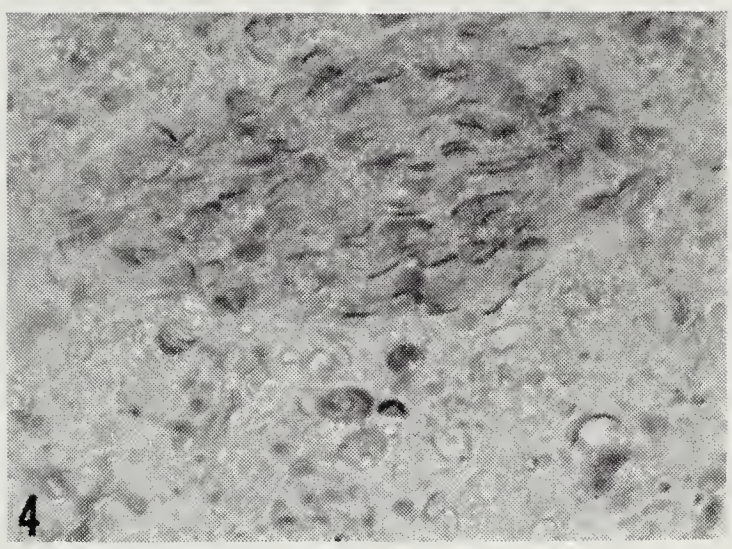
In the cauda epididymis and the vas deferens most of the spermatozoa were also arranged in the orderly stacks described above (Fig. 2). The only exceptions were disordered, scattered spermatozoa in the spindle shaped masses occasionally observed in the lumina of the cauda epididymis and vas deferens (Fig. 3). The PAS method did not reveal any acrosomes in these spermatozoa, although their nuclei were still hematoxylin, Azure B or Feulgen posi-

FIGURE 1.—Spermatozoa forming rouleaux in the spontaneous ejaculate; PAS - Azure B. Reaction X 1,070. (2). Spermatozoa forming rouleaux in the canda epididymis; PAS - Azure B reaction X 1,070. (3). Spindle shaped mass of disintegrating spermatozoa in the cauda epididymis; PAS - Azure B reaction X 430. (4). Spindle shaped mass of disintegrating spermatozoa in the spontaneous ejaculate; PAS - Hematoxylin X 430.









tive (Fig. 3). The whole spindle stained lightly with both Alcian blue and PAS techniques.

The identical masses, with the same staining reactions, were also observed in some of the spontaneous ejaculates (Fig. 4).

DISCUSSION

Experiments conducted by several investigators (Baker, 1931; Austin and Bishop, 1958) indicated that the acrosome in guinea pig spermatozoon is a highly vulnerable and very unstable structure which disintegrated and became detached from the head of spermatozoon soon after the cell died. Leblond and Clermont (1952) reported PAS technique to be specific for intact acrosomes of different spermatozoa. These researchers also noticed in the epididymis of the guinea pig that the successive acrosomes adhered to one another so that the sperm formed closely fitted groups, which the authors called rouleaux (Fig. 2). The spoon-shaped head of the guinea pig spermatozoon probably facilitates such formations (Baker, 1931). The PAS strongly reactive acrosomes and the presence of rouleaux in the spontaneous ejaculates indicate good morphological condition of the ejaculated spermatozoa (Fig. 1).

The spindle-shaped masses in the epididymis and vas deferens of the guinea pig were first reported by Simeone and Young (1931). They based their theory about the fate of unused spermatozoa on this phenomenon (Fig. 3). They proposed that spermatozoa not used in copulation dissolved in the vas deferens to form these masses. In my experiment the negative reaction of massed spermatozoa with PAS technique supported the view that the spermatozoa were dead for a longer time and their acrosomes were disintegrated. However,

both the size and the number of these masses were too small to account for elimination of vast numbers of spermatozoa by dissolution, which in the rat was shown to take four months (MacMillan, 1954). Also, the discovery of spindle-shaped masses in spontaneous ejaculates (Fig. 4) did not support the theory that spermatozoa disintegrate in the upper genital tract of the male.

The presence of morphologically intact spermatozoa in the spontaneous ejaculates of the male guinea pig indicated another way of eliminating surplus spermatozoa. Similar observations have been reported in the rat (Orbach, 1961; Martan and Risley, 1963).

Acknowledgments

This work was partly supported by S.I.U. grant No. 196. The author wishes to thank Mr. Dwight Throgmorton for technical assistance.

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Manuscript received September 1, 1965.

RANGE EXTENSION OF THE LEAST WEASEL AND PIGMY SHREW IN ILLINOIS

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ABSTRACT. — Specimens of the least weasel collected in Woodford, Champaign and Monroe counties and a specimen of the pigmy shrew collected in Monroe County, provide new information on the distribution of these species in Illinois.

The least weasel (*Mustela rixosa*) has been considered an uncommon or rare mustelid in Illinois with a range limited to the northeastern section of the state (Necker and Hatfield, 1941; Hoffmeister, 1956). Since the recording of the Champaign County specimen by Hoffmeister (1956), four other animals have been taken in that county, three within the city limits of Champaign. Hurst H. Shoemaker, Department of Zoology, University of Illinois, Urbana, live-trapped an adult male on February 22, 1958 and kept it in captivity until it accidentally escaped August 10, 1958. Another male was taken July 14, 1961 and this specimen (skin and skeleton No. 26295) was added to the collections of the Museum of Natural History, University of Illinois. The third animal, a male, was caught in a window well in April, 1961 by Richard R. Graber, Illinois Natural History Survey, Urbana, who kept the weasel until its death December 2, 1961. The fourth was caught by a dog two miles northeast of Urbana, March 1, 1962 and was brought alive to Mrs. Richard Graber who kept the animal in captivity until releasing it near the point of capture in October, 1963.

In addition to these four Champaign County records this paper presents an account of remains of *M. rixosa* from two other Illinois counties. One supplements the generally accepted range of this weasel in the north-central region of the state while the other indicates the occurrence of this mustelid in southwestern Illinois, probably in prehistoric times.

On November 17, 1964, the senior author and M. K. Hoffman of the Illinois State Museum staff each collected a short-eared owl (*Asio flammeus*) approximately three and one-half miles east of Minonk, Woodford County. One owl, a male, contained a nearly complete, partially digested carcass of a young least weasel that certainly had been captured the preceding night, probably within a short distance of where these wintering owls were flushed.

The other noteworthy specimen of *M. rixosa* from Illinois consists of the lower jaw and the anterior half of a skull, probably from the same animal; these were recovered in July, 1961 during excavation of a fissure fill located in the limestone bluff of the Mississippi River approximately four miles southwest of Columbia, Monroe County, Illinois (Parmalee, Bieri, and Mohrman, 1961).

While bones of the long-tailed weasel (*Mustela frenata*), representing nearly all elements, were fairly common (124) and at least 10 individuals were represented, only jaw and skull sections of one *M. rixosa* were encountered. This suggests that the least weasel was probably uncommon to rare in that local area. It is impossible to determine the time period in which the least weasel inhabited this section of southwestern Illinois. Recovery of bones of species now occurring further north in Illinois or animals extirpated in the state, plus geological evidence, suggest that the accumulation of animals in this natural death trap began at or soon after the last glacial retreat. Whether these skeletal remains of *M. rixosa* were from an animal of recent occurrence or of one from a prehistoric time period, this Monroe County record extends the range (present or former) of the least weasel

in Illinois approximately 165 miles southwest of its established, southernmost locality (Champaign County).

Hoffmeister and Mohr (1957) state that "The only specimen of the pigmy shrew recorded for Illinois is from Palatine, in Cook County." Recovery of a complete right lower jaw with full dentition and the anterior half of a skull (both I and Pm3; left M_1) of the pigmy shrew (*Microsorex hoyi*) from the same Monroe County cave deposit constitutes the second Illinois record of this northern species and a southwestern extension of its (former or present) range in Illinois of nearly three hundred miles.

Remains of the short-tailed shrew (*Blarina brevicauda*) and the least shrew (*Cryptotis parva*) were abundant in the cave deposit with over 1,000 individuals of the latter species represented. Fifty-one jaw and skull elements of the southeastern shrew (*Sorex* cf. *longirostris*) were recovered; compared with these three species of shrews, *M. hoyi* was rare in that river bluff area. As indicated by the presence of porcupine, least weasel and certain other northern forms, remains of the pigmy shrew from this Monroe County cave point to a prehistoric population rather than an existing one and suggest a more northern and cooler environment at one time in that region of southwestern Illinois.

Acknowledgments

The authors would like to express their appreciation to Drs. Richard R. Graber, Hurst H. Shoemaker and Donald F. Hoffmeister for permission to use their records of the least weasel. We acknowledge with gratitude the specimen of *M. rixosa* donated to the Illinois State Museum by Dr. Graber.

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NEW ALGAL RECORDS FOR KNOX COUNTY, ILLINOIS

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ABSTRACT.—Thirty-six new algal records including six previously unreported in the state of Illinois are recorded for Knox County.

Slightly more than one year ago, Ricker, et al. (1964) reported sixty-nine new algal records for Knox County. Records reported in this paper were observed in collections taken from two sites mentioned in the earlier report (Ricker, et al., 1964) and from a number of new locations: Snake Den Creek, three miles south of Victoria near the Knox College Field Station, Green Oaks; Lake Bracken, an artificial impoundment five miles south of Galesburg; an artificial impoundment in East Galesburg; a water-filled ditch on a railroad right-of-way one-fourth mile east of the Galesburg Municipal Airport; and Railroad Pond, an artificial impoundment one mile west of Rio.

These new records together with those reported earlier (Houdek, 1923; Ricker, et al., 1964) comprise a list of 105 recognized algal taxa for Knox County. Taxa in this list are arranged according to Smith (1950). New records for the state of Illinois are preceded by an asterisk. Preserved samples are on deposit in the herbarium of Southern Illinois University.

Chlorophyceae

Carteria multifilis (Fresenius) Dill. Snake Den Creek, intermittent pond, October 11, 1964, 239.

Phacotus lenticularis (Ehrenberg) Stein. Lake Bracken, October 16, 1964, 240.

Pandorina morum Bory. Lake Storey, October 5, 1964, 238.

Stigeoclonium glomeratum (Hazen) Collins. Lake Bracken, intermittent pond below dam, April 30, 1965, 243.

Stigeoclonium lubricum (Dillwyn) Kuetzing. Green Oaks, main lake, May 1, 1965, 252.

Cladophora glomerata (Linnaeus) Kuetzing. Green Oaks, main lake, May 1, 1965, 247.

Rhizoclonium hieroglyphicum (Agardh) Kuetzing. Railroad Pond, attached to rock in running water below spillway, May 15, 1965, 251.

Pediastrum tetras (Ehrenberg) Ralfs. Green Oaks, main lake, June 10, 1965, 255.

**Crucigenia fenestrata* Schmidle. Lake Bracken, October 16, 1964, 240.

Scenedesmus acutiformis Schroeder. Water-filled ditch on railroad right-of-way one-fourth mile east of the Galesburg Municipal Airport, May 11, 1965, 248.

Closterium dianae Ehrenberg. Railroad Pond, intermingled with *Rhizoclonium hieroglyphicum* in running water below spillway, May 15, 1965, 251.

Cosmarium granatum Brebisson. Lake Bracken, October 16, 1964, 240.

Cosmarium punctulatum Brebisson. Lake Bracken, October 16, 1964, 240.

Euglenophyceae

**Euglena alata* Thompson. Lake Storey, October 5, 1964, 238.

Phacus acuminatus Stokes. Green Oaks, main lake, May 1, 1965, 246.

**Phacus curvicauda* Swirenko. Lake Storey, October 5, 1964, 238.

Phacus longicauda (Ehrenberg) Dujardin. Lake Storey, October 5, 1964, 238.

Phacus spiralis Allegre & Jahn. Lake Bracken, October 16, 1964, 240.

Phacus torta (Lemmermann) Skvortzow. Lake Storey, October 5, 1964, 238.

Trachelomonas abrupta (Swirenko) Deflandre. Green Oaks, main lake, May 1, 1965, 246.

**Trachelomonas bulla* (Stein) Deflandre. Lake Bracken, intermittent pond below dam, April 30, 1965, 243.

Trachelomonas cylindrica Ehrenberg. Lake Storey, October 5, 1964, 238.

Trachelomonas robusta Swirenko. Green Oaks, main lake, May 1, 1965, 246.

Trachelomonas scabra var. *torta* Weik & Mohlenbrock. Lake Bracken, October 16, 1964, 240.

Trachelomonas volvocina var. *punctata* Playfair. Lake Storey, October 5, 1964, 238.

Trachelomonas volvocinopsis Swirenko. Lake Storey, October 5, 1964, 238.

Xanthophyceae

Tribonema bombycinum (Agardh) Derbes & Solier. East Galesburg, artificial impoundment, April 5, 1965, 241.

Vaucheria geminata (Vaucher) DeCandolle. Snake Den Creek, October 11, 1964, 239.

**Vaucheria orthocarpa* Reinsch. Green Oaks, main lake, May 1, 1965, 246.

Vaucheria terrestris (Vaucher) DeCandolle. Lake Bracken, on a moss colony attached to creek bank below spillway, April 30, 1965, 245.

Chrysophyceae

Synura uvella Ehrenberg. Snake Den Creek, October 11, 1964, 239.

Dinophyceae

Peridinium cinctum (Mueller) Ehrenberg. Green Oaks, main lake, June 10, 1965, 255.

Myxophyceae

**Merismopedia tenuissima* Lemmermann. Lake Storey, October 5, 1964, 238.

Oscillatoria agardii Gomont. Lake Bracken, attached to face of spillway, April 30, 1965, 244.

Oscillatoria princeps Vaucher. Lake Storey, October 5, 1964, 238.

Lyngbya spirulinoides Gomont. Green Oaks, main lake, April 22, 1965, 242.

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Manuscript received September 15, 1965.

NOTES ON THE FLORA OF SEVERAL ILLINOIS COUNTIES

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ABSTRACT.—Continued field studies of the flora in Illinois have resulted in the addition of two county records from Alexander, one from Kankakee, and 99 from Washington County.

Specimens cited in this paper are deposited in the Southern Illinois University Herbarium. The following abbreviations are used for collector's names: D, J. R. Dixon; E, T. S. Elias; O, J. E. Ozment; W, D. R. Windler.

ALEXANDER COUNTY

Phacelia ranunculacea (Nutt.) Constance (OW5) and *Forestiera acuminata* (Michx.) Poir. (OW11) are reported as new for the county.

KANKAKEE COUNTY

Equisteum palustre L. (W323) is previously reported only from Peoria and Tazewell counties in Illinois and has not been collected at all in recent years. This specimen from near Bonfield was identified by Robert H. Mohlenbrock, Department of Botany, Southern Illinois University.

WASHINGTON COUNTY

Records seem to indicate that about 500 species were known from Washington County at the publication of the 1960 edition of Winterringer and Evers' "New Records for Illinois Vascular Plants." Many of these records are attributed to the collections of G. H. French who collected in the county before the turn of the century. The following list adds *99* species for the county.

FERNS: *Pteridium aquilinum* (L.) Kuhn (DEW762).
ACERACEAE: *Acer rubrum* L. (W670).
ACANTHACEAE: *Dianthera americana* L. (DEW) 743).
AMARANTHACEAE: *Amaranthus hybridus* L. (W573); *Amaranthus spinosus* L. (W790); *Froelichia gracilis* (Hook.) Moq. (W562).
APOCYNACEAE: *Apocynum cannabinum* L. (W21).
ASCLEPIADACEAE: *Ampelamus albidus* (Nutt.) Britt. (W768).
BETULACEAE: *Corylus americana* Walt. (W207); *Ostrya virginiana* (Mill.) K. Koch (W595).
BIGNONIACEAE: *Catalpa bignonioides* Walt. (W763).
CAMPANULACEAE: *Campanula americana* L. (W217).
CARYOPHYLACEAE: *Silene stellata* (L.) Ait.f. (W587).
CAPPARIDACEAE: *Polanisia dodecandra* (L.) DC. (W762).
CELASTRACEAE: *Celastrus scandens* L. (W704); *Euonymus atropurpureus* Jacq. (DEW711).
CHENOPODIACEAE: *Chenopodium hybridum* L. (W769).
COMPOSITAE: *Cacalia atriplicifolia* L. (W792); *Chrysanthemum leucanthemum* L. (W23); *Eupatorium coelestinum* L. (W34); *Eupatorium perfoliatum* L. (W699); *Eupatorium purpureum* L. (W534); *Helianthus microcephalus* T. & G. (W221); *Senecio glabellus* Poir. (W17); *Tragapogon dubius* Scop. (W759).
CORNACEAE: *Cornus florida* L. (W779); *Cornus foemina* Mill. (W596).
CRUCIFERAE: *Draba brachycarpa* Nutt. (W43); *Draba verna* L. (W44).
EUPHORBIACEAE: *Chamaesyce supina* (Raf.) Moldenke (W218); *Poinsettia dentata* (Michx.) Small (W761).
FAGACEAE: *Quercus macrocarpa* Michx. (DEW731); *Quercus muhlenbergii* Engelm. (W700); *Quercus palustris* Muench. (W690).
GENTIANACEAE: *Frasera carolinensis* Walt. (W667).

HYPERICACEAE: *Hypericum prolificum* L. (W574).
JUGLANDACEAE: *Carya glabra* (Mill.) Sweet (W777).
LABIATAE: *Lamium amplexicaule* L. (W45); *Lamium purpureum* L. (W46); *Scutellaria australis* (Fassett) Epling (DEW736); *Scutellaria ovata* Hill (W797).
LAURACEAE: *Lindera benzoin* (L.) Blume (W547).
LUGUMINOSAE: *Desmodium cuspidatum* (Muhl.) Loud. (W785); *Lespeeza repens* (L.) Bart. (W791); *Stylosanthes biflora* (L.) BSP. (DEW722).
LOBELIACEAE: *Lobelia cardinalis* L. (W54).
MALVACEAE: *Abutilon theophrastii* Medic. (W553); *Malva neglecta* Wallr. (W557).
NYCTAGINACEAE: *Mirabilis nyctaginea* (Michx.) MacM. (W675).
ONAGRACEAE: *Jussiaea repens* L. (DEW738, W801).
PASSIFLORACEAE: *Passiflora lutea* L. (W205).
POLEMONIACEAE: *Phlox paniculata* L. (W592).
POLYGONACEAE: *Polygonum convolvulus* L. (W774); *Polygonum cristatum* Engelm & Gray (W775); *Polygonum hydropiperoides* Michx. (DEW740); *Polygonum persicaria* L. (W575); *Rumex crispus* L. (W765); *Rumex triangulivalvis* (Danser) Rech. f. (W775); *Rumex verticillatus* L. (W s.n. June, 1961).
RANUNCULACEAE: *Anemone virginiana* L. (W589); *Clematis viorna* L. (DEW716); *Ranunculus abortivus* L. (W s.n. June, 1961); *Thalictrum revolutum* DC. (DEW754).
ROSACEAE: *Agrimonia rostellata* Wallr. (W798); *Amelanchier arborea* (Michx.) Fern. (DEW732); *Aruncus dioicus* (Walt.) Fern. (DEW728); *Crataegus crus-galli* L. (W581); *Crataegus mollis* (T. & G.) Scheele (W552); *Fragaria virginiana* Duch. (W9); *Potentilla monspeliensis* L. (DEW746); *Rubus allegheniensis* Porter (W540); *Rubus ostryifolius* Rydb. (W60).
RUBIACEAE: *Galium concinnum* T. & G. (DEW721); *Houstonia minima* Beck (W39).
SOLANACEAE: *Datura stramonium* L. (W767); *Physalis heterophylla* Nees (W s.n. July, 1961).
STAPHYLEACEAE: *Staphylea trifolia* L. (W585).
URTICACEAE: *Boehmeria cylindica* (L.) Sw. (W216).
VITACEAE: *Vitis riparia* Michx. (W683); *Vitis vulpina* L. (W697).
COMMELINACEAE: *Tradescantia ohiensis* Raf. (W18).
DIOSCORACEAE: *Dioscorea villosa* L. (DEW713).
GRAMINEAE: *Agrostis scabra* Willd. (W681); *Cenchrus pauciflora* Benth. (W757); *Echinochloa muricata* (Michx.) Fern. (W803); *Panicum capillare* L. (W800); *Panicum commutatum* Schult. (DEW714); *Panicum lindheimeri* Nash. (DEW733); *Paspalum laeve* Michx. (W782, W787); *Paspalum pubiflorum* Rupr. (W568); *Setaria faberi* Herm. (W760); *Sorghum halepense* (L.) Pers. (W766).
LILIACEAE: *Asparagus officinalis* L. (W771); *Hemerocallis fulva* L. (W773); *Nothoscordum bivalve* (L.) Britt. (W s.n. May, 1961); *Smilax bona-nox* L. (W702); *Smilax pulverulenta* Michx. (DEW729); *Smilax rotundifolia* L. (W594); *Uvularia grandiflora* Sm. (DEW712).

Manuscript received September 7, 1965.

MYXOMYCETES IN SOUTHERN ILLINOIS

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ABSTRACT.—This survey of southern Illinois Myxomycetes has resulted in a list of 78 species from the southern twelve counties. Among these are three new to the state of Illinois. These are *Badhamia lilacina*, *Stemonitis carolinensis*, and *Stemonitis webberi*. This brings the total number of Myxomycetes known from Illinois to 147.

While little study has been made on the Myxomycetes of Illinois (McCleary & Groeklags, 1965), even less has been done with the species which occur in the southern tip of the state. Benjamin (1956) reported 40 collections representing 24 species from the southernmost twelve counties of Illinois. A collection of about twenty species was obtained in the early 1940's by John McCree, a plant collector hired by the Works Progress Administration.

Later collections from southern Illinois were made by the late Dr. Leo Kaplan and Dr. Walter B. Welch, professors of Botany at Southern Illinois University. Mr. D. Wain Garrison, a former student at Southern Illinois University, made a number of collections from Jackson and Williamson Counties in 1957. All collections mentioned above except those by Benjamin are deposited in the herbarium of Southern Illinois University.

The bulk of this paper is based on a thesis (Folkerts, 1963) prepared for partial fulfillment of the requirements for the Degree of Master of Science in the Department of Botany of Southern Illinois University.

The area encompassed by this study includes the twelve southernmost counties of Illinois. These are Randolph, Jackson, Williamson, Saline, Gallatin, Union, Johnson, Pope, Hardin, Alexander, Pulaski, and Massac Counties.

Because of the infinite variety of possible habitats for Myxomycetes, no definite collecting stations were set up, although areas which proved productive were visited a number of times. Among these were the Pine Hills area near the small town of Aldridge in Union County, Giant City State Park near Makanda, located in southern Jackson County and northeastern Union County, and Thompson's Woods, located on the campus of Southern Illinois University, Carbondale.

Although collections were made in all months of the year, the most intensive collecting was done in the spring and summer because of the comparative abundance of fructifications during these seasons.

Some use was made of moist chamber technique in attempting to produce fructifications on various substrates. Plastic boxes measuring 3¼ x 2¾ x 1⅜" were used for the chambers. A thoroughly moistened piece of paper toweling was included to provide the needed humidity. Portions of bark from living trees, wood from decaying logs, and small quantities of decaying leaves and organic detritus were placed in the chambers until fructifications appeared. Moisture was added at intervals if deemed necessary.

Fructifications collected in the field were permanently placed in small boxes for storage in the herbarium. Toward the end of the study, it was found that the specimens were more easily taken out for examination if they were glued to a piece of stiff paper, rather than to the box itself.

The majority of collections were identified by the use of three works. These were *Monograph of the Mycetozoa*, 3rd edition (Lister, 1925), *Myxomycetes* (MacBride and Martin, 1934), and *North American Slime Molds* (Martin, 1949). The publication by Lister is uniquely useful because of the numerous excellent illustrations. The most complete work, and also the one with the most useful key, is that of Martin, which unfortunately contains no illustrations.

Ecology

Little has been written on the ecological relationships of slime molds, although some information can be obtained from lists of habitats or substrates on which the fructifications have been found. During the course of this study, careful notes were made on the type of substrate on which the fructifications were found, the amount of moisture present in and on the substrate, and the general ecological nature of the surroundings.

From the findings of this study, it is evident that Myxomycetes vary greatly in moisture tolerance, substrate specificity, and affinities for any certain ecological niches.

Attempts were also made to determine whether or not certain species produced fructifications at definite times of the year or in response to certain climatic conditions.

Since assumptions cannot be drawn about species collected only a few times, most of the ecological data are restricted to the common species (i.e., species whose fructifications were collected or observed at least fifty times during the course of this study).

The following summarizes some of the ecological data obtained:

Affinities for producing fructifications on the bark of living trees, *Licea biforis*; on decaying wood only, *Lycogala epidendrum*, *Dictydium cancellatum*, *Hemitrichia clavata*, *Hemitrichia stipitata*, *Ceratiomyxa fruticulosa*, *Comatricha aequalis*, *Arcyria denudata;* on decaying wood and organic detritis, *Calonema aureum*, *Oligonema schweinitzii*, *Diderma effusum;* on living herbs, *Physarum cinereum;* on a variety of substrates, *Fuligo septica*.

In southern Illinois, the best season of the year in which to collect slime molds appears to be the summer, especially during June and early July. Fructifications of most of the species included in this study can be observed at this time.

Few slime molds can be collected during the winter months. The only species which was noticed to produce fructifications during every month of the year was the trichiaceous *Calonema aureum*.

The conditions which induce the production of sporangia are probably variable from species to species, and little definite information is available on this subject. It does seem, however, that a period of drying immediately following an exceptionally wet period, accompanied by high temperatures, is the best time to expect the production of fructifications.

As is to be expected with any group of plants, some species are exceptionally common, and others quite rare. The following is a list of the ten most common species in southern Illinois, arranged with the most common placed first:

Hemitrichia vesparium
Hemitrichia stipitata
Lycogala epidendrum
Arcyria cinerea
Ceratiomyxa fruticulosa
Calonema aureum
Fuligo septica
Dictydium cancellatum
Physarum nucleatum
Stemonitis fusca

The apparent abundance of some of these species is probably due to the persistence of the sporangia. Fructifications of *Hemitrichia vesparium* may remain recognizable for several months after they are produced, whereas those of *Ceratiomyxa* and *Fuligo* usually disappear within a few days.

Four species were found in the attempts to produce fructifications on wood and detritis placed in moist chambers. These were *Arcyria cinerea*, *Licea biforis*, *Echinostelium minutum*, and *Cribraria minutissima*. Of these, *Cribraria minutissima* and *Licea biforis* were obtained only by the moist chamber method. The other two species were collected also in the field.

The following summarizes the species and the substrates on which they were found: *Echinostelium minutum* on *Ulmus americana*, *Quercus* sp., *Taxodium distichum;* *Licea biforis* on *Populus deltoides;* *Arcyria cinerea* on *Ulmus americana*, *Quercus* sp.; *Cribraria minutissima* on *Ulmus americana*.

By far the most abundant slime mold found by the moist chamber technique was *Echinostelium minutum*. Fructifications of this species may be produced on almost any piece of bark from *Ulmus americana*. Gilbert and Martin (1933) have pioneered in the field of moist chamber technique.

Annotated List of Species

The nomenclature for the taxa in the annotated list follows Martin (1949).

Counties from which specimens have been taken are listed following each species. A single asterisk (*) indicates the first report from southern Illinois. A double asterisk (**) indicates the first report from the entire state.

* *Ceratiomyxa fruticulosa* (Mull.) Macbr. Moist rotting logs in lowland areas. Alexander, Jackson, Johnson, Pope, Union.

* *Licea biforis* Morgan. Bark of *Populus deltoides* (in moist chambers). Jackson.

* *Tubifera microsperma* (Berk. and Curt.) G. W. Martin. Moist rotting wood. Jackson.

* *Lycogala epidendrum* (L.) Fries. Moist wood in almost any type of habitat. Alexander, Gallatin, Jackson, Johnson, Pope, Saline, Union, Williamson.

* *Lycogala exiguum* Morgan. Dead Wood. Hardin.

* *Dictydiaethalium plumbeum* (Schum.) Rost. Moist decaying wood. Union.

* *Enteridium rozeanum* (Rost.) Wingate. Moist decaying wood. Union.

* *Cribraria violacea* Rex. Dead wood, bark of living trees, on mosses. Union.

* *Cribraria minutissima* Schw. Bark of living trees, dead wood, on mosses. Jackson (in moist chamber).

* *Cribraria intricata* Schrad. Moist decaying wood. Pope, Williamson.

* *Dictydium cancellatum* (Batsch) Macbr. Moist decaying wood. Alexander, Jackson, Johnson, Pope, Williamson.

Echinostelium minutum DeBary. Decaying wood, bark of living trees, dung. Jackson, Johnson, Union (in moist chamber).

* *Perichaena chrysosperma* (Currey) Lister. Dead wood, dung. Jackson.

* *Perichaena depressa* Libert. Dead bark, decaying wood, detritis, dung. Gallatin, Jackson, Union.

* *Perichaena corticalis* (Batsch) Rost. Decaying wood and dung. Union.

* *Arcyria incarnata* (Pers.) Pers. Moist decaying wood. Jackson.

* *Arcyria magna* Rex. Wet decaying wood. Johnson. Reported by McCleary and Groeklags (1965) for the first time from Illinois (DeKalb Co.).

Arcyria cinerea (Bull.) Pers. Dead wood, plant debris, dung. Alexander, Jackson, Johnson, Massac, Pope, Union.

* *Arcyria insignis* Kalchbr. & Cooke. Dead wood, herbaceous stems. Pope.

* *Arcyria denudata* (L.) Wettst. Moist decaying wood. Gallatin, Jackson, Johnson, Pope, Union, Williamson.

Oligonema flavidum (Peck) Peck. Decaying wood. Pulaski.

* *Oligonema schweinitzii* (Berk.) G. W. Martin. Decaying wood, detritis. Alexander, Jackson, Massac, Saline.

Trichia varia (Pers.) Pers. Dead wood. Johnson, Pope, Saline, Union.

* *Trichia contorta* (Ditmar) Rost. Dead wood. Jackson.

* *Trichia scabra* Rost. Moist decaying wood. Gallatin, Hardin, Pope, Randolph, Union.

* *Trichia favoginea* (Batsch) Pers. Moist decaying wood. Johnson.

* *Trichia affinis* DeBary. Decaying wood, detritis. Jackson, Union.

* *Trichia persimilis* P. Karst. Decaying wood, Alexander, Jackson.

* *Hemitrichia serpula* (Scop.) Rost. Decaying wood and litter in moist ravines. Gallatin, Jackson, Saline, Union, Williamson.

* *Hemitrichia clavata* (Pers.) Rost. Moist decaying wood. Alexander, Jackson, Johnson, Union.

Hemitrichia stipitata (Massee) Macbr. Rotting wood and leaves. Alexander, Gallatin, Hardin, Jackson, Massac, Pope, Pulaski, Randolph, Union, Williamson.

* *Hemitrichia vesparium* (Batsch) Macbr. Decaying wood. Alexander, Gallatin, Hardin, Jackson, Johnson, Pope, Pulaski, Randolph, Saline, Union, Williamson.

Calonema aureum Morgan. Alexander, Jackson, Johnson, Pulaski, Saline, Union.

* *Diachea leucopodia* (Bull.) Rost. Fallen leaves and twigs, living plants. Jackson, Williamson.

Stemonitis fusca Roth. Decaying wood, leaves. Alexander, Gallatin, Jackson, Johnson, Pope, Union.

** *Stemonitis webberi* Rex. Dead wood. Jackson.

Stemonitis axifera (Bull.) Macbr. Johnson, Pope, Williamson.

* *Stemonitis smithii* Macbr. Decaying wood. Alexander, Pope. Reported by McCleary and Groeklags (1965) for the first time from Illinois (DeKalb Co.)

** *Stemonitis carolinensis* Macbr. Dead wood. Pope.

* *Comatricha nigra* (Pers.) Schroet. Decaying wood. Williamson.

* *Comatricha elegans* (Racib.) Lister. Decaying wood. Jackson.

* *Comatricha typhoides* (Bull.) Rost. Decaying logs, leaves. Jackson, Union, Williamson.

* *Comatricha aequalis* Peck. Moist decaying logs. Alexander, Jackson, Johnson, Union.

* *Lamproderma arcyrioides* (Sommerf.) Rost. Dead wood, plant detritis. Alexander.

Lamproderma arcyrionema Rost. Dead leaves, wood. Williamson.

* *Lamproderma scintillans* (Berk. & Br.) Morgan. Wood, decaying plant material. Jackson.

Macbrideola scintillans H. C. Gilbert. Bark of living trees (in moist chamber.) Union.

Macbrideola decapillata H. C. Gilbert. Bark of living trees (in moist chamber). Union.

* *Fuligo septica* (L.) Weber. Almost any type of substrate. Hardin, Jackson, Pope, Union, Williamson.

* *Fuligo cinerea* (Schw.) Morgan. Rotting vegetation, manure, bark of dead trees. Union.

Badhamia foliicola Lister. Dead wood, plant detritis. Jackson, Johnson.

** *Badhamia lilacina* (Fries) Rost. Decaying wood and herbs. Williamson.

* *Physarum cinereum* (Batsch) Pers. Decaying leaves, soil, living plants. Jackson.

Physarum bivalve Pers. Dead leaves, plant debris. Johnson.

* *Physarum globuliferum* (Bull.) Pers. Decaying wood. Pope.

* *Physarum pulcherrimum* Berk. & Rav. Decaying wood. Williamson.

* *Physarum stellatum* (Massee) G. W. Martin. Dead wood and decaying wood. Pope.

* *Physarum nucleatum* Res. Dead and decaying wood. Jackson, Pope.

* *Physarum pusillum* (Berk. & Curt.) G. Lister. Plant debris. Union.

* *Physarum tenerum* Rex. Decaying wood, twigs, plant debris. Hardin, Pope.

* *Physarum polycephalum* Schw. Dead wood, fleshy fungi. Gallatin, Jackson, Union.

* *Physarum nutans Pers.* Dead wood. Jackson, Johnson, Pope, Williamson.

Physarum viride (Bull.) Pers. Decaying wood, plant debris, old fungi. Alexander, Jackson, Johnson, Pope, Williamson.

* *Craterium leucocephalum* (Pers.) Ditmar. Decaying leaves, twigs, wood. Williamson.

* *Craterium minutum* (Leers) Fries. Decaying leaves, twigs, wood. Jackson, Union, Williamson.

Physarella oblonga (Berk. & Curt.) Morgan. Decaying wood, leaves, fungi. Alexander, Jackson, Johnson, Williamson.

* *Leocarpus fragilis* (Dicks.) Rost. Decaying leaves, twigs, wood, and living herbs. Williamson.

* *Mucilago spongiosa* (Leysser) Morgan. Dead wood and leaves, stems of living plants. Jackson.

* *Diderma globosum* Pers. Dead wood, twigs, living plants. Jackson.

* *Diderma testaceum* (Schrad.) Pers. Dead leaves, plant debris, fungi. Jackson, Pope, Union, Williamson.

Diderma effusum (Schw.) Morgan. Decaying leaves and wood, dung, living herbs. Johnson, Pope.

* *Diderma floriforme* (Bull.) Pers. Decaying wood. Gallatin, Jackson.

Didymium squamulosum (Alb. & Schw.) Fries. Decaying plant material, dung. Johnson.

Didymium melanospermum (Pers.) Macbr. Decaying wood, twigs, leaves. Williamson.

Didymium minus (Lister) Morgan. Decaying wood and plant material. Jackson, Johnson, Massac, Williamson.

Didymium nigripes (Link) Fries. Decaying plant material. Massac.

Clastoderma debaryanum A. Blytt. Decaying wood. Jackson.

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Manuscript received August 19, 1965.

SOME AQUATIC PHYCOMYCETES FROM PINE HILLS

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ABSTRACT. — *Rhipidium thaxteri*, a New World record; *Mindeniella spinospora*, a state record; and as yet an undescribed Genus and species, were collected on immature fruits suspended at various depths in Otter Pond.

During the summer of 1964, three unusual rhipidiaceous fungi were collected at the Pine Hills Field Station in southwestern Illinois. All collections were obtained on fruits submerged in Otter Pond, a former meander of the Big Muddy River in the Mississippi River flood plain. The fruits were enclosed in wire cages, suspended at various depths in the water, and were removed and replaced at two-week intervals.

Rhipidium thaxteri Minden, Figure 1, a and Figure 2, a-d.

R. thaxteri was described from Germany (Minden, 1912, 1916) and has since been found only in China (Shen and Siang, 1948). Collections from Otter Pond were obtained on immature fruits of apple, crabapple, pear, rose, wild goose plum, hawthorne, grape, persimmon, and on the fleshy seeds of *Ginkgo;* the collections were made during July, August and September. The material from Illinois differed only slightly from the description given by Sparrow (1960), the measurements being as follows: discoid portion of the basal cell up to 300μ broad, the lobes reaching 100μ wide at their extremities; fertile filaments 4-6μ in diameter, swollen apically and constricted at the sporangial base; sporangia mostly 60-80 X 16-25μ, the overall range 43-97 X 13-29μ; oogonia 36-50μ above, tapering downward; antheridia 7-10μ, in diameter, attached at the apex of the oogonium; oospores 25-37μ in diameter.

Although many thalli of *R. thaxteri* were found, few bore sexual structures.

Mindeniella spinospora Kanouse, Figure 1,b.

There have been few reports of collections of *M. spinospora* (Sparrow, 1960) and none that we are aware of from Illinois. Collections were made in July and August on immature fruits of apple, grape and persimmon. The sporangia were spineless in most instances, and none of the thalli observed bore resting spores. Many of the thalli were contorted and asymetrical, resmbling those of *M. asymetrica* Johnson (1951). However, zoospore size and other characteristics appeared to be those of *M. spinospora*.

Collections of an as yet undescribed genus and species (Fig. 1, c-d and Fig. 2, e,f) were made during July, August and September. This fungus has previously been reported from Africa, Central America, Louisiana and Florida (see Stuehling and Ziegler, 1959). Specimens from Otter Pond were compared with material from Florida (Ziegler coll.) and were found to be the same. The species grew in abundance on immature fruits of apple, crabapple, pear, wild goose plum, persimmon, trumpet flower, grape and peach. The sporangia and resting spores are similar to those of *Mindeniella*, but they lack spines and are apedicellate. The zoospores too, are morphologically similar to those of *Mindeniella*. Cultures of this species were established in the laboratory on pears and wild goose plums. Although typical thalli developed, no sporangia or resting spores formed. According to Weston (personal comm.) the species will be described in the near future.

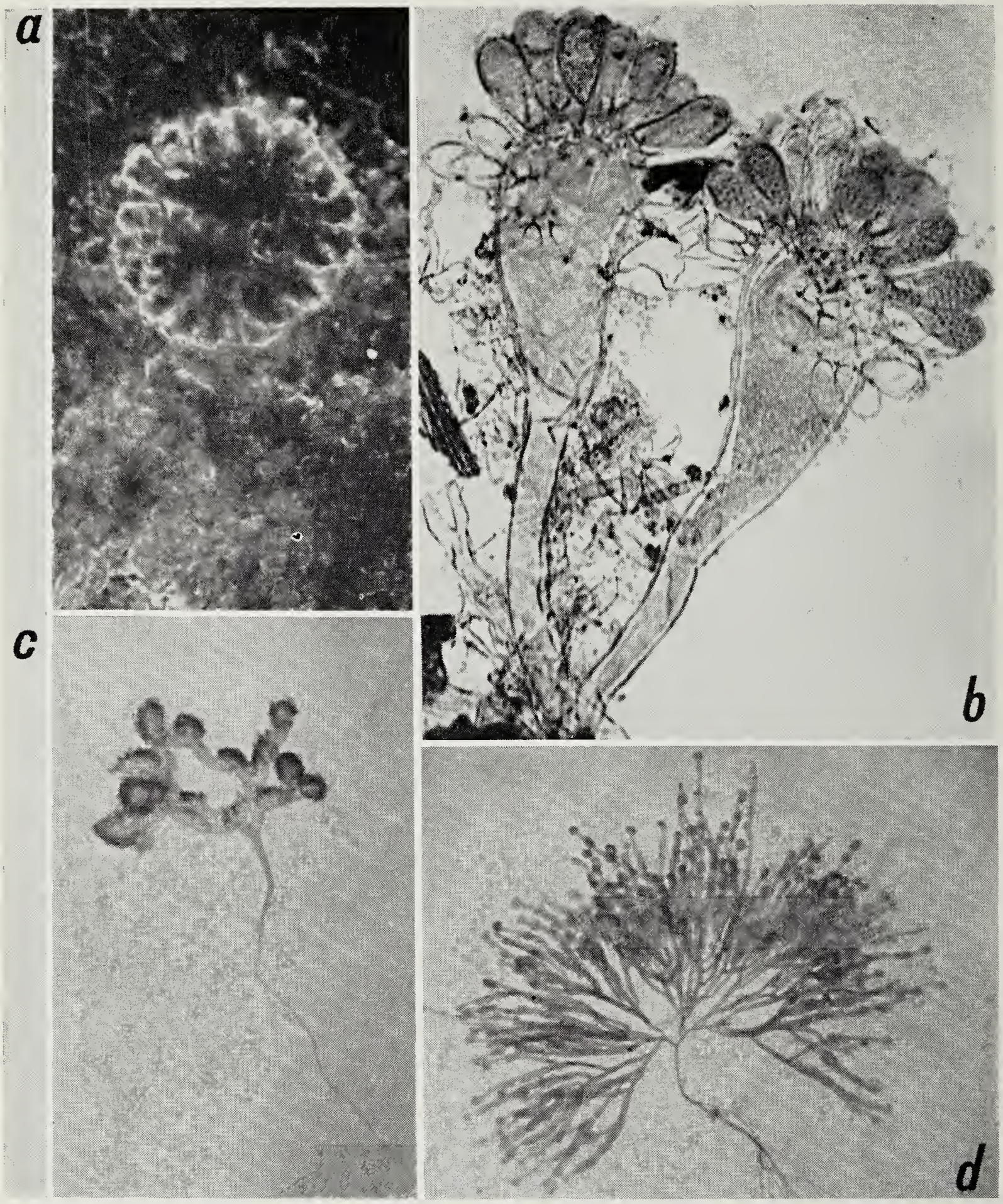

FIGURE 1.—Illustrations of, a, discoid basal cell of *Rhipidium thaxteri* (X150); b two thalli of *Mindeniella spinospora* (X160); and c, d. the habit of the undescribed species (c, X 10; d, X 7).

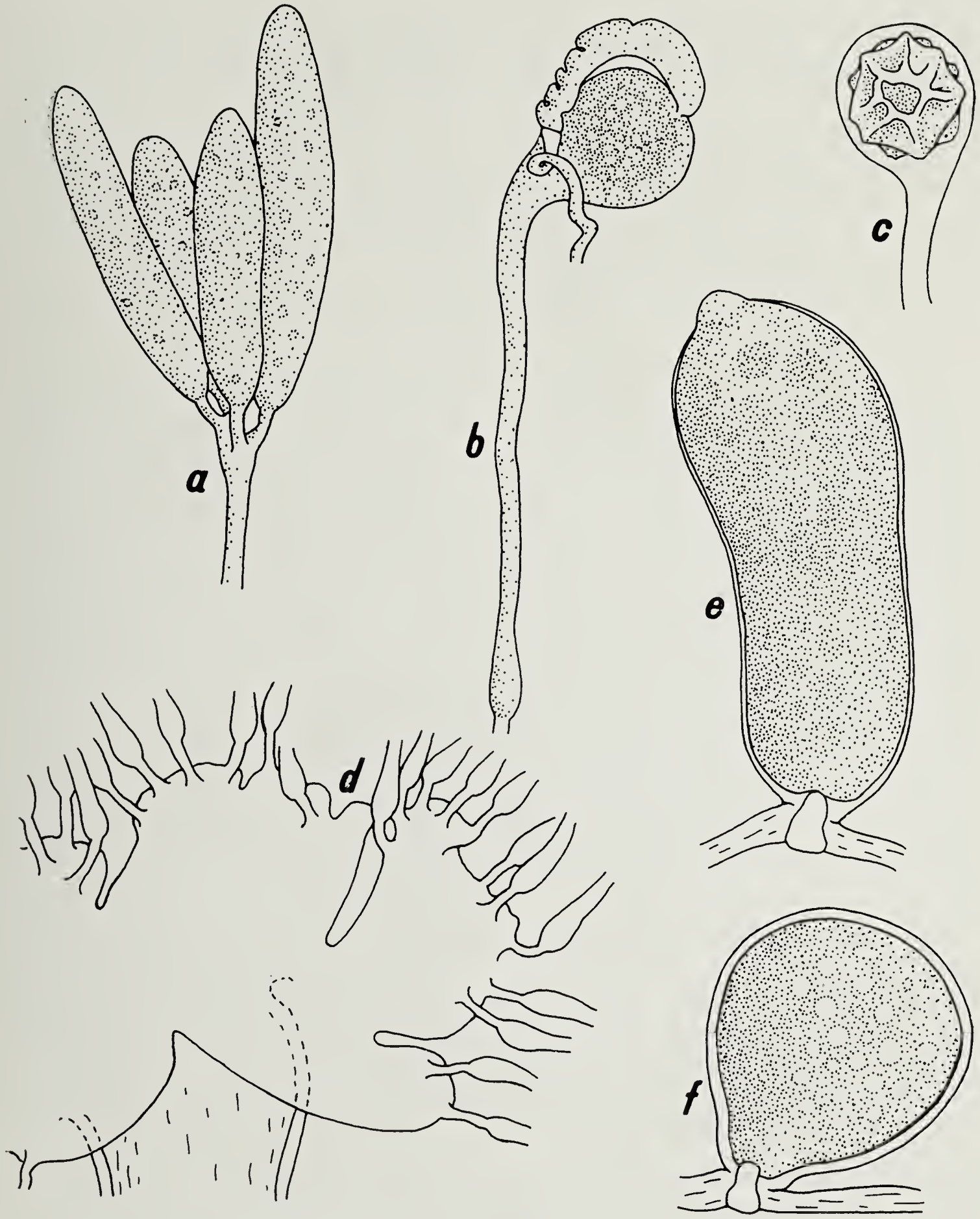

FIGURE 2.—Illustrations of, a-d, *Rhipidium thaxteri.* a, sporangia; b, oogonium with attached antheridium; c, oogonium and mature oospore; d, apical disc of basal cell showing origin of fertile filaments; and e, f, sporangium and resting spore of an undescribed species (a-c, e and f, X 700; d X 500).

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Manuscript received September 2, 1965.

THE AVERAGING PROCESS FOR ITERATIVE ASSOCIATION CONSTANTS

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ABSTRACT.—An investigation is made of the effect of averaging (over wavelength) before iterating in the spectrophotometric determination of association constants. A numerical example is obtained by considering binary solutions of nitroparaffin-carbon tetrachloride solutions. It is found that convergent values are obtained for the spectroscopic constants and for the concentration constant. However, the values of the concentration constant are shown to be unreliable.

Recently Musulin, et al. (1962) have shown that a spectrophotometric iteration procedure (Keefer and Andrews (1952)) for concentration constants was improperly specialized to the problem of association reactions (de Maine, et. al. (1957)). Further, Musulin (1965) has demonstrated that the first iterate obtained by this procedure is unreliable. However, Haigh (1963) has provided a proof showing under what conditions a modification (de Maine, et. al. (1960)) of this method is valid. The principal feature of the modified method involves an averaging process. It is the purpose of this paper to explore the use of the modified method for binary solutions containing a nitroparaffin.

PROCEDURE

The experimental details of the preparation and measurement of the solutions are given by Foley, et al. (1964). All calculations were performed on an IBM 1620 digital computer. The program was written in FORTRAN II. If the first approximation provided a negative concentration constant, that value was replaced by $K_c = 100$ for the purpose of continuing the iteration procedure. In order to thoroughly test the method, some K "poor" data (hereafter designated as RLF (2-3) and RLF (3-3)) were used in the calculations. These data showed deviations from Beer's Law (Prutton and Maron (1951)) which upon remeasurement were proven untrue for these solutions (cf. Musulin, (1965)). Excess significant figures for some solutions appear in this report in order to maintain internal consistency.

RESULTS

As shown in Musulin (1965), a great variation is obtained in the values of the first approximation of K_c. With one exception, all average values changed by less than 1% for those data which adhered to Beer's Law. Similarly, the changes in the extinction coefficients were slight upon recycling. Table 1 tabulates some sample results.

TABLE 1.—First Differences in the Spectroscopic Constants and the Concentration Constant Obtained from Various Successive Cycles of the Modified Iteration Procedure for Representative Binary Solutions of Nitroparaffins.

Sample	$(K_c)_{av}$			$(\epsilon_d)_{max}$		$(\epsilon_m)_{max}$	
	$\triangle^{12}$	Δ^{23}	Δ^{34}	Δ^{12}	$\triangle^{23}$	Δ^{12}	$\triangle^{23}$
WML (3-3)	.01	.05	.05	.03	.00	1.49	.00
RLF (4-3)	.03	.05	.04	1.17	.00	4.87	.00
RLF (2-3)	4.63	4.51	4.47	2.17	1.66	24.07	25.00

In this table, K_c is the concentration constant; $(K_c)_{av}$ is its average value for all wavelengths; ϵ_d and ϵ_m are the extinction coefficients of the dimer and monomer, respectively; and $\triangle^{pq}$ is the % change in the value in going from cycle p to cycle q.

If the system obeys Beer's Law, the values of the extinction coefficients converge at the end of the second cycle. The changes in the monomeric value are greater than that for the dimeric value. On the other hand, if the system does not obey Beer's Law, convergence is much slower. In every instance the successive changes in K_c are essentially constant but small. The smallness is essentially nugatory if the system obeys Beer's Law.

Table 2 summarizes the spectroscopic constants and the average values of K_c obtained in this study. In this table, λ is the wavelength and the subscript "max" indicates the value at the absorption maximum. All values are those obtained at the end of the third cycle, i.e. one cycle after stability is reached for those systems obeying Beer's Law. The range indicated on K_c and ϵ_{max} is the least square deviation (Baten (1938)).

Finally, the effect of changing variables was explored. Two types of changes may be significant. The first is the variation due to experimental technique. The second is the effect of significant figures used in the calculation. Table 3 presents some representative values showing these effects.

In this table, a third digit in the identification gives the day of measurement, a prime on the second digit means a second "identical" solution, and the first digit is coded as follows: 1—rounded concentration value, 2—(concentration value + estimated experimental error), 3—mean concentration error, and 4—(concentration value —estimated experimental error). For example, if the concentration is given as 0.10 M, the solution is designated by 1 while if the concentration is given as 0.0497M, then a 3 is used to designate the solution.

From Table 3 it is apparent that solution aging produces slight changes in spectroscopic values but even these play havoc with K_c values. The same effects, but even more pronounced, result when an experimenter attempts to duplicate the original solution. Finally, the number of significant figures is very important to the final values of K_c, but again, slight change is noted in the values of spectroscopic constants.

Discussion

Haigh (1963) showed that the modified method converges if $\epsilon_m > \frac{1}{2}\ \epsilon_d$. The results of Table 2 indicate that this condition is fulfilled for binary solutions of nitroparaffins in the concentration range studied. Further, Table 1 verifies that convergence is truly obtained. However, if the values of $(K_c)_{av}$ from Table 2 are compared to the values of $|\overline{K^{(1)}}|$ given by Musulin (1965) a striking similarity is noted. The only differences occur in those instances where a value of $K^{(1)} < 0$ is replaced by $K^{(1)} = 100$. The present method can only be useful if a good method of obtaining $K^{(1)}$ is at hand. The choice used in this work is not reliable (Musulin, (1965)) and the method of arbitrar-

Table 2.—The Spectroscopic Constants for Monomeric and Dimeric Forms and the Concentration Constant Obtained from the Modified Iteration Procedure for Various Nitroparaffinic Binary Solutions.

Solvent	Solute	Solution Identification Code	$(\lambda_d)_{max}$ (mμ)	$(\epsilon_d)_{max}$ (l/mole-cm)	$(\lambda_m)_{max}$ (mμ)	$(\epsilon_m)_{max}$ (l/mole-cm)	$(K_c)_{av}$
CH_3NO_2	CCl_4	WML (3-3)	280	37.95 ± .28	280	36.04[1]	793.22 ± .55
		RLF (1-3)	279	43.83 ± 1.97	277	24.85	897.54 ± 2.80
		RLF (4-3)	279	35.92 ± .74	277	27.80	176.04 ± .11
	H_2O	WML (1-3)	270	26.54 ± .55	270	35.53	535.46 ± 1.19
$C_2H_5NO_2$	CCl_4	WML (4-3)	280	48.37 ± 3.75	260	40.63	180.72 ± .88
		RLF (2-3)	279	131.39 ± 20.36	273	1.00	13.08 ± .02
	H_2O	WML (2-3)	270	35.80 ± .24	280	25.24	864.17 ± 1.54
n-$C_3H_7NO_2$	CCl_4	RLF (3-3)	281	37.12 ± 5.85	279	41.81	119.29 ± 18.29
i-$C_3H_7NO_2$	CCl_4	RLF (4-1)	279	47.19 ± 0.78	281	28.56	106.90 ± .12

[1] Lowest λ value omitted.

TABLE 3.—The Effect of Chemical and Numerical Experimentation upon the Values of the Spectroscopic Constants for Monomeric and Dimeric Forms and the Concentration Constant Obtained from the Modified Iteration Procedure for Sample Nitroparaffinic Binary Solutions.

Solvent	Solute	Solution Identification Code	$(\lambda_d)_{max}$ (mμ)	$(\epsilon_d)_{max}$ (*l*/mole-cm)	$(\lambda_m)_{max}$ (mμ)	$(\epsilon_m)_{max}$ (*l*/mole-cm)	$(K_c)_{av}$
CH_3NO_2	H_2O	WML (1-3-0)	270	26.54 ± .55	270	35.53	535.46 ± 1.19
		WML (1-3-3)	270	26.86 ± .84	270	33.34	389.52 ± .56
		WML (1-3-0)	270	25.85 ± .82	270	45.52	1752.01 ± 3.27
CH_3NO_2	CCl_4	RLF (4-1)	279	36.81 ± .56	217	33.66	572.64 ± .22
		RLF (4-2)	279	35.21 ± .73	277	27.10	141.79 ± .10
		RLF (4-3)	279	35.92 ± .74	277	27.80	176.09 ± .11
		RLF (4-4)	279	36.46 ± .66	277	28.60	206.65 ± .11

ily selecting a starting point (de Maine, et al. (1960)) would lead to an infinitude of K_c values. Therefore, although the method is mathematically convergent, it is of no practical utility for determining K_c.

This work verifies (as has been stated by Haigh) that the initial values of ϵ_d and ϵ_m are very good, (in a convergent sense). In CCl_4, the values of ϵ_d are slightly larger than those of ϵ_m and about twice the values of the average extinction coefficient of the system (cf Foley, et. al. (1964)). In general λ_{max} is the same for the two species. Consequently, if dimerization occurs in this system, it has only a slight perturbative effect on the $\pi^* \leftarrow n$ transition responsible for the absorption.

Acknowledgment

This work could not have been completed without the cooperation of the Computing Center of Southern Illinois University who so willingly donated professional advice, machine time, and supplies. A portion of this work was supported by a Grant (602-B) from the Petroleum Research Fund administrated by the American Chemical Society.

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Manuscript received February 6, 1965.

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Edwin C. Galbreath,
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Southern Illinois University,
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BOTANICAL GARDEN

Transactions

of the

Illinois State Academy of Science

Volume 59
No. 2
1966

Springfield, Illinois

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OF THE

ILLINOIS STATE ACADEMY OF SCIENCE

VOLUME 59 - 1966 No. 2

Illinois State Academy of Science

affiliated with the

Illinois State Museum Division

Springfield, Illinois

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

Otto Kerner, *Governor*

June 15, 1966

CONTENTS

Presidential Address—"A Dangerous Thing"
by G. Robert Yohe 101

A History of Science Education in the Illinois State Academy of Science
by Walter B. Hendrickson 108

The Cyperaceae of Illinois
by Robert H. Mohlenbrock 114

The Funk Forest Natural Area, McLean County, Illinois: Woody Vegetation and Ecological Trends
by W. R. Boggess and J. W. Geis 123

The Vascular Flora of the Mississippi Palisades State Park, Carroll County, Illinois
By R. P. Wunderlin 134

The Illinois Species of Haloragaceae and Hippuridaceae
by Miriam Wysong Meyer and Robert H. Mohlenbrock 149

Distribution of Lycaenidae (Lepidoptera) in Illinois
by John C. Downey 163

Animal Remains from the Stilwell Site, Illinois
by Fredrick C. Hill 169

Winter Food of the Short-eared Owl, *Asio flammeus*, in Illinois
by Edward A. Munyer 174

Changes in the Livers of Mice Fed Polyoxyethylene Sorbitan Derivatives
by Jim N. Tone 181

Effect of Antimetabolites, Pyridine Derivatives, Metallic Salts and Intermediary Metabolites on Rat Diaphragm Metabolism
by Leon L. Gershbein 187

News and Comments 191

Demountable Cell Holder Adapter for Broken Infrared Salt Windows
by R. E. Van Atta and John Hollis 193

Patterns of Cell Death in Elongating Corn Stalks
by A. J. Pappelis and Judith R. Williams 195

Additions to the Vascular Flora of Carroll County, Illinois
by R. P. Wunderlin 199

Nutrient Content as Related to Senescence in Sugar Cane
by Walter E. Schmid, A. J. Pappelis, and Simeon K. Imbamba 201

PRESIDENTIAL ADDRESS

"A DANGEROUS THING"

G. ROBERT YOHE
Illinois State Geological Survey, Urbana

". . . You will know the truth, and the truth will set you free." (John 8:32)

I suppose that of all the quotations I might give from the Bible, this one is most likely to receive the approval of scientists, and I should like to recapitulate very briefly some of our interpretations of it. But in reality, I have not quoted the Bible; I have misquoted it. I have given you only half a sentence, separated from its context.

We can all cite many an instance wherein the fruits of research, the scientist's means of learning the truth, have given us greater freedom in one way or another. I think, for example, of our freedom from poliomyelitis today. Those of us who were raising our children 25 years ago, when the local newspapers kept a daily running score of the polio cases in the county much as they list the holiday week-end traffic fatalities today, remember very well the dread of those long summers and the dull, aching apprehension we felt when we learned that a child in the next block had been stricken.

In our own land and times, we are so familiar with our freedom from hunger, from menial tasks, and from ignorance of all that is going on in the world that there is really no need to discuss the details of the advances that have been made in agricultural practices, mechanical and electrical power, transportation and communications. The many liberties provided by our science and technology are taken for granted.

The gaining of these liberties, however, has involved the paying of a price. In achieving some freedom from hunger by learning the secrets of plant cultivation and establishing agriculture, man gave up the freedom to roam when and where he pleased and became tied down to his plot of land. We have gained freedom from much work because of our electric motors and gadgets, but we have become almost completely dependent upon our public utilities companies—have you ever thought of the consequences of a week long total power failure in a large city? [I have deliberately left that sentence as I wrote it late last summer.

Since that time, many people have thought very seriously of the consequences of such a power failure, because on November 9, 1965, starting late in the afternoon when many thousands of workers were homeward bound, New York City and a large adjacent territory did experience about twelve hours without electricity.] Many a person has been freed from some of the manual chores of housekeeping, only to be enslaved by the television set. We have released the energy of matter, and now find ourselves captured by the greatest fear that man has yet confronted — the terror of atomic war.

But when we look more closely at some of these fears and enslavements that we pay as the price for our freedoms from discomfort and toil, we notice an interesting fact: we do not fear nor mistrust our mechanical and scientific gadgets. We have confidence in the dependability of our power plants and transmission lines. We recognize, of course, that storm, flood, and earthquake may cause their disasters, but our linemen soon restore the service, and life goes on. We like the comforts and safety of our snug homes so much that we would not trade these features for the freedom of a nomadic life, no matter how much we glamorize that kind of existence in our daydreams. We are not afraid of our automobiles, although we are rightly apprehensive about the way certain careless or irresponsible people handle them. We point with some pride to the achievements of our plant breeders, our entomologists, and our agronomists in vastly increasing the productivity of our food-growing acres. We would not be afraid of famine if it were not for the fact that we can see the startling rapidity with which our populations are increasing. We do not fear atomic power as such; but we are mightily afraid of the complete and utter disaster that will surely result if that power is not used wisely. In short, we do not fear our science or technology; we fear people. We, as human beings, are scared to death of ourselves.

Yet we say that knowledge is the key to solving our difficulties, and it has become almost a by-word in our language that education is to be the salvation of mankind. Our troubles are inflicted upon us, we say, because we do not have sufficient education—if we just knew more about the universe around us, if we only had more of the truth about things and people, we would know how to live together peaceably and safely. And this is obviously true, if we define education as the learning, understanding, and application of all those things we need to know in order to avoid our troubles. But have we defined it thus? What can our present status teach us on this point?

We may be sure, I believe, that if each one of us were to keep his car, to the best of his ability, in sound mechanical condition, and drive it at all times in conformity with the existing laws and with due courtesy to the other drivers on the highways, the killing and maiming tragedies that occur by the thousands each week would be largely eliminated. We have the knowledge, but we do not use it.

I believe that one of the most important lessons we can learn from the history of civilization is that just and lasting solutions to problems are seldom if ever formed in the flaming forge of war. Misunderstanding is fostered, and hatred is deliberately fanned by propaganda and atrocity stories, and an all-pervading feeling of goodwill cannot be achieved instantaneously with the signing of a peace treaty. We know these things, but we are men, not mice, and as human beings throughout the world, we ignore them and continue our fighting ways.

Let us come back to that which is closer to our individual lives, and is fundamental to our larger, more obvious problems. We know the principles of brotherly love, and as a "Christian" nation, we pay lip service to them. Yet the evidences of our selfishness and greed are manifest in many tell-tale actions that are so small that we think them insignificant. We strive to get "our share of things," even though we deprive another citizen of his. We are litter-bugs on the highways; we manipulate pay telephones ("If it rings twice and stops, put the roast in the oven — I'm starting home. And I get my dime back."); we evade taxes; we misrepresent merchandise. We smile graciously at someone near the head of a long cafeteria line, ask politely, "May I step in here, please?" and blithely cheat every person in the remainder of the line out of a half-minute of his time. We really know better than to do these things, but we do not use our knowledge.

All this, I hope, will let us emphasize one point: we make a serious mistake when we take for granted that an increase in knowledge will automatically confer upon us a corresponding increase in wisdom. Knowledge and wisdom are by no means synonymous, and facts are but a part of the truth for which we seek.

We hear much about the exponential growth of knowledge that is taking place today, and I would agree that the providing of food, energy, and shelter for an increasing population requires an increase in knowledge. We must cause two blades of grass to grow where previously there was but one.

But what of our need for wisdom?

Perhaps it would be well to pause here to define wisdom. My dictionary gives as the first meaning, "accumulated philosophic or scientific learning." I am not using the term in this sense, but rather in accordance with the next items given: "ability to discern inner qualities and relationships," and "good sense." Under synonyms for the word "sense," my reference states: "wisdom implies sense and judgement far above average."

Let us picture one human being, living by himself in an isolated tract. To survive, he needs some knowledge of what to eat and how to get it; knowledge of how to protect himself from various dangers. But he has no problems of coexistence with others of his kind.

Next, let us imagine the arrival of another human being in the same territory. Now they will require twice the food that our one man needed, and perhaps twice the shelter space. Protection, on the other hand, may be less difficult, if they are wise

enough to help each other. For now we have problems of personal relationships that require the exercise of wisdom. If they are to live together, they must be able to cooperate, and to avoid personal conflict.

Suppose that our tiny community again doubles in population. Four people will need twice the food that two required, but where we formerly had only one personal contact (A with B), we now have six two-way combinations (AB, AC, AD, BC, BD, and CD) where friction may arise, where warmth and friendliness may exist, but where, in any case, the exercise of wisdom is needed . . . It would not be surprising if, at this point, some of you have thought of the Biblical story of Adam and Eve, Cain and Abel.

To double this group again and consider only the two-way interactions would involve calculating the possible combinations of eight things taken two at a time, and we find that although the food requirements would only double, the binary contacts would go up to 28. With 16 in the community, these would mount to 120; with 32, 496. Thus the village in this last case would require 16 times the food that two persons would need, but provide nearly 500 times the opportunities for personal conflicts and trouble. And this is vastly over-simplified because only the binary contacts are counted—no "triangles" are considered.

Who can say that doubling the knowledge of the facts of agriculture is needed to double the food supply, or that the distribution of necessities to a doubled population requires double the knowledge of transportation? Who can say that the total quantity of wisdom needed is directly proportional to the number of human contacts that occur? These involve concepts that defy measurement. Yet it does seem that while the need for certain physical items may increase linearly with an increase in population, the human contacts that need the sound judgment and good sense that we call wisdom tend to increase at an increasing rate.

Thus we have an ever-growing need for wisdom; a need which we may not be able to fulfil for our present adult population. Can we hope that our on-coming generations may develop greater wisdom than that possessed by their parents?

It is relatively easy for a person to gain knowledge by attending classes or by reading, but how can we impart wisdom to our growing youth? Is wisdom gained from the lecture room, from the television set, or from the printed page? Certain foundations may be laid thus, of course, but we really cannot give our students wisdom, ready-made, to be dropped into their lives for immediate use like a battery into a flashlight. Each person, by devoting time and effort to deep pondering and serious thought, must develop his own concepts, ideas, and evaluations that lead to wisdom. A relatively ignorant man can be wise, and one who possesses a great fund of knowledge may be pathetically lacking in wisdom.

Are we today engaged in such a rat-race of education that we are shortchanging our youth in the wisdom-gaining pursuits? Are we try-

ing to crowd so much of the newly discovered scientific information into our high school and college courses that we leave our students (and ourselves) no time to think? Are we pushing them so hard that they consider it appropriate to blow up in foolish revelry when a brief vacation arrives?

We tell our students that their time is precious, and that it should be budgeted so that none is wasted; so that they may study their text assignments, work their problems, and learn their lessons. We require that they take certain courses in physical training, and encourage their participation in athletics, because they need physical as well as mental exercise; because their bodies must be kept strong and healthy. We urge them to attend festivals of music and the arts, because a rounded education should include an appreciation of "the finer things of life." We schedule, or expect them to do so, various social activities, dances, parties, and entertainments because they need some "recreation." It is good, we say, to keep them busy, and to see that even their leisure time is filled with activity.

It may not be accidental that some of our greatest works of wisdom and our highest types of religious teachings have come from inhabitants of arid, semidesert regions. In those areas there is solitude. There the people can see the heavens through a clear and unpolluted atmosphere; they can get unobstructed views of the distant hills. In such surroundings, people can realize more easily how small they are, after all. For example, the Psalmist said (Psalm 8):

> When I look at thy heavens, the work of thy fingers,
> The moon and the stars which thou hast established;
> What is man that thou art mindful of him,
> And the son of man that thou dost care for him?

Jesus of Nazareth, according to the accounts we have of his life, spent several weeks alone in the wilderness before he started his career of ministry and teaching. There he faced and overcame certain temptations to misuse his abilities, and he set the course he was to follow so steadfastly.

Other cultures have taken steps to meet this problem. We are told that certain American Indian tribes were wont to send each boy, as he approached manhood, out into the wilderness to fast and meditate until he had received a vision of some significance. He had no books for entertainment; no games to help him while away his time. He was alone with his thoughts. Longfellow portrayed it in his "Song of Hiawatha:"

> You shall hear how Hiawatha
> Prayed and fasted in the forest,
> Not for greater skill in hunting,
> Not for greater craft in fishing,
> Not for triumphs in the battle,
> And renown among the warriors,
> But for profit of the people,
> For advantage of the nations.
> First he built a lodge for fasting,
> Built a wigwam in the forest,
> By the shining Big-Sea-Water,
> In the blithe and pleasant Spring time,
> In the Moon of Leaves he built it,
> And, with dreams and visions many,
> Seven whole days and nights he fasted.

Our own culture is not completely devoid of all vestiges of such a custom. Within the framework of the Boy Scouts of America there is an organization known as The Order of the Arrow. Each boy taken into it

must spend a night alone in the "wilderness," which is usually some lonely spot in the back acres of his Council's camp area. One young man (who happened to be an Assistant Scoutmaster rather than a Scout) came in the next morning with this poem as evidence that he had been thinking during the night:

Who, in the night,
Under nothing but the trees,
Has ever been alone?
He, perhaps,
Who, for his light,
Depends upon his brother's torch,
And not upon his own.
But he,
Who down inside,
Carries warmth enough,
And pride,
Can light the living forest
So that nothing there can hide;
And then it is he sees
Where they dwell among the trees
That a hundred thousand friends are shown,
And that here he cannot be alone.

—Harlan K. Corrie
May 10, 1952

Most of us, as scientists, believe in using laboratory methods in teaching. Although laboratory work is costly and time-consuming, we acknowledge its worth because the actual handling of objects and the seeing of results impress the memory more firmly and stimulate reasoning more surely than the mere reading of descriptions of work done by others. Perhaps we should consider quiet and undisturbed meditation as the laboratory work of evolving one's own philosophical outlook, or at least the testing and evaluation that should precede the acceptance of material one reads. And perhaps the temptation to do a lot of reading should be resisted at times; we are too much prone to look for profundities in the words of "recognized authorities," and too little prone to dig them out for ourselves.

What effect would it have on our lives if each one of us, starting at about the age of the college freshman, were to spend a week each year alone with his thoughts? Given a plain but comfortable cabin for shelter, with a picture window overlooking an isolated lake, a landscape of mountain fastnesses, or the solitude of a Grand Canyon vista; given simple but adequate food and drink; but given no books or papers to read, no radio or television for entertainment, no puzzles for pastime, what would be the result? Would it be madness nurtured by boredom, or would it be a revised and wiser outlook on life? How many Thoreaus do we lose for want of their Walden Ponds?

Or, on a far simpler scale, how many potential thinkers are stunted in their development because they ride to school in crowded buses amid the chatter of trivial conversation rather than walk a mile or two alone each day?

You may wonder, by now, what all this has to do with science. Simply this: we, as scientists, need to be "taken down a peg or two." We have too much of a tendency to point to our science as the deliverer of mankind; to hold up our education in science as the hope of human salvation. Too many of us have made Science our God, and Scientism our religion. We have vastly increased our knowledge, and we have emphasized our need for yet more of it, but we have forgotten wisdom. We need to stop and think of the folly of this negligence.

But please do not misunderstand me; I am not making a plea for curtailing our scientific efforts. And I am aware that some of our better colleges are indeed instituting programs designed to meet this problem and give their students new opportunities to think.

I should like to read a paragraph that I found in an item entitled "Scientific Understanding and the Chief End of Man" in NATURE, Vol. 207, p. 1070 (September 4, 1965): D. M. Mackay, in *Man and his Future* (Churchill, London, 1963) ". . . has already pointed out that it was concern for truth which begot science, not science which begot concern for truth. It is argued that to continue to pursue the truth, which is, in its essentials, the pursuit of a moral goal, by means which have already successfully brought material wealth, food, healing, and understanding of Nature and of man himself, is a worthy end for human endeavour."

A man or a woman who has gained wisdom bids fair to be an excellent citizen, regardless of his or her attainments in the fields of factual knowledge. But the person who has a great deal of knowledge without the necessary wisdom for using it may well be the unrecognized enemy in our midst, for it is not just "a little knowledge," but rather knowledge without wisdom that is truly "a dangerous thing."

Wisdom is attainable. Not by the application of thermometers, polarimeters, spectrometers, or cyclotrons housed in multimillion dollar laboratories, but by the appropriate use of equipment that is so commonplace that it is quite unspectacular, and so long in the possession of the human race that it has never held the glamor of novelty—our own brains. These are more readily available to us than coffee breaks, more marvelous than computers, more portable than transistors—and much more neglected than they should be. They can be tricky, and they require the expenditure of effort to operate them. To use them can be productive; to leave them idle is tragic.

Perhaps religion deserves our earnest attention here, for as I see it, a serious and thoughtful pursuit of religion is in essence a striving for wisdom. Many people, by blind acceptance of dogma, make it much less than this, so I am using the phrase, "thoughtful pursuit of religion," advisedly.

When we succeed in attaining the proper balance of wisdom with factual knowledge, we may well find that this is the goal we seek, and that this is the real meaning of the complete sentence, part of which I read at the outset: "If you abide by what I teach, you are really my disciples, and you will know the truth, and the truth will set you free."

Presented at the 59th Annual Meeting of the Illinois State Academy of Science, Normal, Illinois. April 22, 1966.

A HISTORY OF SCIENCE EDUCATION IN THE ILLNOIS STATE ACADEMY OF SCIENCE

WALTER B. HENDRICKSON, *Professor of History*
MacMurray College, Jacksonville, Illinois

The Illinois State Academy of Science was founded in 1907 and, although a separate section on science teaching was not created until 1960, one of the earliest and longest continued activities of the Academy was a concern for the teaching of science in the high schools of the state.

The founders of the Academy were overwhelmingly college teachers but there was a sprinkling of high school teachers. Both groups felt that too often the science courses of the high schools were taught by improperly prepared teachers using inadequate textbooks and limited teaching materials. Professor John G. Coulter, then on the faculty of Illinois State Normal University (now Illinois State University), said in 1908, "Untrained teachers had had nature thrust upon them, and have [*sic*] turned with avidity toward whatever seemed to offer help. Composites of sentiment and inaccuracy have been liberally supplied as supplementary reading." (1)

Coulter declared that this situation was a challenge to the Academy and he urged that it undertake the publication of a series of leaflets on science subjects especially applying to Illinois. These should be sold to the schools for a small sum. Such a project had been successful in New York where Cornell University had put out a series of nature study and agricultural leaflets.(2) This project was discussed by the Council and in annual meetings for several years, one committee after another dealing with it. They got as far as to prepare a list of topics and assign authors, but they were never able to find a means of financing the project so that it would be under the control of the Academy. They rejected the idea that the pamphlets should be published by the State.(3)

Another matter much in the minds of the members of the Academy in its early years was the correlation of "pure" and "applied" science. By applied science was meant courses in agriculture and home economics (or domestic science as it was often called). These subjects, especially agriculture, had been taught in some high schools for many years, but more and more schools were taking them up. In 1914 the idea was given the broad support of the Smith-Hughes and Smith-Lever Acts under which federal funds were supplied to the states for the payment of the salaries of teachers of agricul-

ture and home economics. These subjects were considered to be "scientific" in that they rested to a considerable extent on the results of scientific research. The United States Department of Agriculture through the land grant universities and experiment stations was even then turning out great numbers of publications on soil fertility, plant nutrition, insect control and many other subjects. Chemists, entomologists, and biologists were increasingly being employed in these activities. Many scientists felt that these courses would displace the older traditional science courses in zoology and botany, and that the student, rather than having a thorough grounding in science, would be taught those things that were "practical" and which applied specifically to the subject matter of agriculture and domestic science.

This was the situation in 1909 when the Academy held a symposium on pure and applied science. Worallo Whitney of Bowen High School in Chicago pointed out that only 13% of the entire curriculum of Illinois high schools was devoted to any kind of science. There was a loose sequence of natural science in the lower years and physical science in the upper grades. He also had found that the applied sciences were given without any relation to other science courses and that no prerequisite in theoretical science was required. Whitney recommended that at least a single course in general science (by which he meant mainly physical science), be required before students could take agriculture or domestic science.(4)

So much steam was generated by the symposium that John Hessler, Professor of Chemistry at Millikin University, moved the appointment of a committee of five "to discover whether the Academy may be of assistance to the high schools of the state in the teaching of science, and if so, to report at the next meeting a plan of action, and that the Council [of the Academy] shall be authorized to place at the disposal of the committee such files and correspondence as may seem expedient."(5)

The committee, which was named the Committee to Investigate the Relation of the Pure and Applied Sciences to the High Schools, made several reports in the next few years, and it did not confine itself strictly to the subject matter of the title. It ranged over the whole field of science in the high schools, finally dropping entirely the question of correlating the pure and applied sciences. Partly, this was because it became clear, as Professor Hessler said, that a good teacher in the applied sciences would always give his students basic work and would illustrate the principles of science from the particular course he was teaching.(6) In recognition of the fact that the question of pure versus applied science was a dead issue, but that there were other aspects of science teaching in the high schools that needed the attention of the Academy, the name of the committee was changed in 1914 to the Committee on High School Science, and later was sometimes referred to as the Committee on Secondary Science.(7) This committee and its

predecessor, in their reports, informed the Academy on several matters that were being discussed by high school and college teachers about science teaching in the high schools.

Teaching methods, course content, textbooks, apparatus, and other aspects of the subject were reviewed by the committee in the light of the new progressive educational aims and methods that were sweeping the country at the time. In 1914 Woralo Whitney reported on the need for revising current high school courses, which he called "hand-me-down" college courses. He said that "pupils were not interested, little enthusiasm could be aroused, [and] many pupils failed, . . . only the brightest pupils got anything out of the course." Whitney considered the courses of the time to be too technical and too divorced from the pupils' daily life. His remedy for this bad situation was to give a revised course which he called "Laboratory and Field Course in Botany." In this course the student would begin in the fall by collecting and studying seeds and fall flowers and, during the winter, would study the lower plants in the laboratory. When spring came the pupil would go outdoors again to study seedlings, roots, stems, leaves, and even do some gardening for himself. According to Whitney, who had taught such a course, the student's interest was aroused and, at the same time, the scientific side of botany was not neglected.

Whitney reported that the changes which he had made in his courses were also being made in other high schools and in the other sciences of zoology, physics and chemistry.(8)

Another matter discussed in the Academy meetings during the pre-World War I period was the high school general science course or, as it was sometimes called, the "unified" science course. Harold B. Shinn of Carl Schurz High School of Chicago reported on the work of the National Education Association and the Central States Association of Science and Mathematics Teachers, both of which were developing such courses. Shinn also summarized a bulletin of the United States Bureau of Education on the proper aims of high school science courses. He said that the Agricultural Section of the Illinois High School Conference was also working toward the same ends. He said that "no organization has yet considered the formulation of a general course in high school science in which there shall be not only unity or consensus of purpose and method, but even more a close articulation or, to put it more plainly, an almost entire absence of demarcation between the natural sciences."(9)

In 1915 and 1916 papers were presented to the Academy on other aspects of science teaching in the high school. At the same time (1916) the secretary of the Academy, noting that the membership of the Committee on High School Science was depleted to the point where only John Hessler was still active, told the Academy that a committee of this kind was of vital importance to the Academy. He continued, "It seems that we have made almost no progress in our endeavor to form some kind of workable relations with high schools of the state, and yet I believe that we should persist until something is accomplished in this

line. I believe we should have a sort of junior membership to which the high schools and colleges supporting science clubs of one sort or another would be eligible, and I believe that it might be possible to affiliate those clubs with the Academy through a junior membership.'' (10) This secretary was J. L. Pricer, then teaching biology at Normal University. Thus it was as a gleam in his eye that the idea of the flourishing Junior Academy of the 1960's was first brought to the attention of the Illinois State Academy of Science, although it was a decade before the first hesitant steps were taken toward the establishment of the Junior Academy.

In 1917 Professor Hessler, then chairman of the Committee on High School Science, pressed the Academy to do something, saying that its members could perform no greater service than to improve science teaching in their communities. He reported with regret that little had been accomplished so far in getting high school teachers to join the Academy and attend its meetings. He went on to say that if the Academy was to succeed in interesting high school teachers, the members should know more about the situation in the schools.(11) The result of the prodding by Hessler and Pricer was the presentation of a symposium on science and education in 1918. Some of the most eminent members of the Academy spoke. William A. Noyes of the University of Illinois talked about the need for more general knowledge and training in chemistry. He advocated a four-year high school science course which would include physiology, botany, zoology, physics, and chemistry.(12) Rollin D. Salisbury of the University of Chicago spoke on the earth sciences, saying that ''no subject affords better field for the development of the sort of attitude of mind which seems especially to fit everyday life.''(13) Others addressed themselves to agriculture, biology, and physics, each claiming that his subject was indispensable. Fred Barber of Illinois State Normal University talked about the reorganization of high school science courses, and he suggested a two year sequence in general science, with the first year course on the physical sciences and the second year on the natural sciences, and he said both courses ''should emphasize the connection of science and human welfare.''(14) Although it is doubtful whether the Academy members learned very much from the symposium about the actual conditions in the high schools, they resolved to appoint a committee of five to study the suggestions that were made.(15) Nothing ever came from the committee.

Professor Pricer continued to tell the Academy that it could best assist science education by getting high school science clubs to affiliate with the Academy. The Academy did appoint a committee on High School Science Clubs, and Pricer was named chairman.(16) From this time — 1919 — to the present, the chief activity of the Academy in science education has been to work with high school science clubs and, later, with the Junior Academy of Science which developed out of the meetings of these club members with the Academy.

When Professor Pricer died in 1920, the committee on high school science clubs was reconstituted and carried on its work much as Pricer had outlined it. High School clubs in the vicinity of the annual meetings were invited to send delegates. In 1923 at the Galesburg meeting, a high school section was organized for teachers and sponsors of clubs and it was reported that a lively session was held.(17) The Academy voted to give the Committee on High School Science and Clubs (the two committees had been combined in 1922) fifty dollars to carry on its work.(18)

The high school section attracted large attendance for the next few years. Papers were read on how to "humanize" science and thus interest students in science, how to organize science clubs, and how to conduct lively programs. But so far as the record shows, although the number of clubs affiliated with the Academy rose from 7 to 22, the first time students met in their own meeting at the same time as the Academy was in 1929 when prizes were given to students for the best exhibitions of chemical products. This was the first time the name "Junior Academy of Science" was used, the first time a business meeting of the students was held, and the first time an exhibition of student projects was displayed.(19)

Also from 1929, the section on high school science was dropped, and one on psychology and education took its place, but the programs concerned research rather than teaching methods. Science teaching received an occasional notice in the regular subject-matter sections and in 1937 the botany section met in two parts, one on research and the other on the problems of teaching botany.(20) In 1949 there was a general session devoted to science education, but the papers presented were more inspirational than practical.(21) Undoubtedly this meeting was held in response to the post-World War II rethinking of high school and college curricula.

Beginning in 1950 a few papers, mostly how-to-do-it in content, were given in the psychology and education section. This section, always disjointed, became more so when social science was added in 1953.(22) But, because the importance of science education was so great and there was such growing interest in it, the name of the section (which had become a place where high school teachers exchanged ideas) was altered in 1956 to science education, psychology, and social science. This made the section uninteresting to high school teachers, who were in the majority, and when the psychologists and social scientists found that they had an unappreciative audience they retired. In 1960, therefore, the section went through still another reorganization and became simply the section on science teaching.(23)

After 1960, at the science teaching section meetings, papers were given on such subjects as methods of teaching gifted children, and on the use of special apparatus to illustrate scientific phenomena.(24) With the rise of the participation of the Federal government in science education, attention was paid to the evaluation of some National Science Foundation programs.(25) In the chemistry section papers were presented on the

content of new or rearranged courses for high school students and college freshmen — the Chemical Bond Approach (CBA), and the Chemical Educational Materials Study (CHEMS). (26)

The Academy has had a continuing interest in the preparation of high school teachers, and the committee charged with this matter reviewed the Illinois state requirements for certification. In 1965, on the basis of its report, the Academy passed a formal resolution addressed to the Superintendent of Public Instruction urging that the hours required for professional education courses be limited to sixteen, and that a minimum of 24 semester hours be required in the subject matter of a student's major subject. (27)

In a matter related to science education, the Academy early began to pass resolutions urging that the governor and the legislature provide adequate financing and a proper building for the Illinois State Museum. (28)

Another area, that of educational moving pictures, also interested the Academy. In 1950 a committee was created to evaluate movies on scientific subjects. Until 1963, the chairman of the committee was Milton D. Thompson. When he moved from Associate Director of the Illinois State Museum to Director, the chairman became Herman Eifert, also on the museum staff. The evaluations made by this committee were offered to high school teachers, and provided valuable guidance in a field of science education where there was much that was not scientific. (29)

Literature Cited and Notes

1. Illinois State Academy of Science, *Transactions*, I (1908), 39. All following citations, unless otherwise noted, are from this source, and only volume number, date, and page number will be given.
2. I (1908), 39.
3. V (1912), 16; VI (1913), 12-13; VII (1914), 9.
4. III (1910), 7.
5. *Ibid.*, 89.
6. VIII (1915), 18-20.
7. VII (1914), 9.
8. *Ibid.*, 151-71.
9. *Ibid.*
10. X (1917), 24.
11. *Ibid.*, 130-34.
12. XI (1918), 59.
13. *Ibid.*, 70.
14. *Ibid.*, 65.
15. *Ibid.*, 11.
16. XII (1919), 91-92.
17. XVI (1923), 48.
18. *Ibid.*, 73.
19. XXII (1929), 622.
20. XXVIII (1935), 7.
21. XLII (1949), 17-34.
22. XLVI (1953), 6.
23. LVIII (1960), 213.
24. Illinois State Academy of Science, Program of the Annual Meeting, 1962, p. 12.
25. *Ibid.*
26. *Ibid.*, 8.
27. LVIII (1965), 215-16.
28. V (1912), 16-18; LIII (1960), 76.
29. See for example LIII (1960), 83-89.

Manuscript received November 13, 1965.

THE CYPERACEAE OF ILLINOIS

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ABSTRACT.—This is a continuation of the Cyperaceae of Illinois (Parts I - VII, Am. Midl. Nat. vols. 63, 67, 69, 70). Five species of *Eriophorum*, 7 of *Rhynchospora*, 1 of *Cladium*, and 4 of *Scleria* are treated. Keys, descriptions, and discussions are included.

This paper is a continuation of the Cyperaceae of Illinois. Other parts in this series, all in the American Midland Naturalist, have been: I. *Cyperus* 63:270-306, 1960. II. *Dulichium* 67:398, 1962. III. *Eleocharis* 67:398-423, 1962. IV. *Bulbostylis* 69:441-444, 1963. V. *Fimbristylis* 69:444-452, 1963. VI. *Lipocarpha* 69:452-455, 1963. VII. *Scirpus* 70:1-46, 1963.

Two species of *Fuirena* have been attributed to Illinois — *F. pumila* Torr. by Fernald (1950) and *F. squarrosa* Michx. from Union County by Patterson (1876). No specimens could be found.

VIII. ERIOPHORUM

Eriophorum is a Linnean genus of primarily northern, bog-inhabiting species. The first report of *Eriophorum* in Illinois was by Engelmann (1843) when he listed *E. angustifolium* and *E. gracile*.

With the exception of *E. angustifolium*, which is known from nine counties, the Illinois species of *Eriophorum* are exceedingly rare, being known only from one or two counties. All five species are confined to the northern third of the State.

MORPHOLOGY OF THE SPECIES

The species of *Eriophorum* in Illinois are slender or rather robust, usually tufted perennials, with terete or angular stems. The stems, which are glabrous or scabrous, may attain a height of about one meter in *E. virginicum*. The leaves are usually flat at the base, becoming triangular-channeled to nearly conduplicate near the subulate tip. Sometimes the leaves are channeled throughout. The margins are often scabrous.

There are 1-5 erect or spreading involucral bracts which are frequently reddish or purplish near the base. They range from 1-12 cm long.

Although species with single spikelets occur in the genus, only species with 2-30 spikelets occur in Illinois. The spikelets are borne on glabrous, scabrous, or puberulent peduncles. The acute or obtuse scales are castaneous, greenish, or lead-colored. They elongate during anthesis. There are 1-3 stamens and a 3-cleft style.

The sharply trigonous achene is 1.5-4.0 mm long and usually apiculate. The numerous, naked bristles are white or cream and greatly elongated in fruit, forming the conspicuous "cotton-heads."

SYSTEMATIC TREATMENT

Eriophorum L. Sp. Pl. 52. 1753.

Key to the Illinois Species of *Eriophorum*

1. Leaves 0.5-1.5 mm wide, channeled throughout; involucral bract 1.
   2. Culms glabrous throughout; sheath of leaf longer than blade; achene 1.5-2.0 mm long..... .....1. *E. gracile*
   2. Culms scabrous above; sheath of leaf shorter than blade; achene 2.5-3.0 mm long....2. *E. tenellum*
1. Leaves 1.5-8.0 mm wide, channeled only above the middle; involucral bracts 2-5.

3. Stamens 3; scales one-nerved.
   4. Peduncles glabrous; anthers 2.5-5.0 mm long ....3. *E. angustifolium*
   4. Peduncles puberulent; anthers 1.0-1.5 mm long..... .....4. *E. viridicarinatum*
3. Stamen 1; scales several-nerved.. .....5. *E. virginicum*

1. *Eriophorum gracile* Koch ex Roth, Cat. Bot. 2:259. 1800.

Very slender perennial with glabrous, terete culms to 60 cm tall; leaves channeled throughout, to 4 cm long, 1.5 mm broad, rounded at the apex, the uppermost sheath longer than the blade; involucral bract 1, erect, channeled throughout, 1-2 cm long, dark gray to black at base; spikelets 2-5 (-6) on slender, puberulent peduncles up to 3 cm long, the spikelets elliptic to ovoid, 7-10 mm long in flower, 12-18 mm long in fruit; scales lead-colored or blackish, obtuse or subacute; anthers 1.2-2.0 mm long; achenes 1.5-2.0 mm long; bristles numerous, white.

Habitat.—Bogs.

Range.—Labrador to Alaska, south to California, Illinois, and Delaware; Europe; Asia.

This species, because of its terete stems, its elongate leaf-sheaths, its blackish scales, and its smaller spikelets and achenes, can be separated rather easily from *E. tenellum.*

The only two records of this species' occurrence in Illinois were during the nineteenth century.

Specimens Examined.— Peoria Co.: Peoria *Brendel s.n.* (ILL). Northern Illinois, *Vasey 18642* (ILL).

2. *Eriophorum tenellum* Nutt. Gen. Am. 2 Add. 1818.

Eriophorum gracile var. *paucinervum* Engelm. in Am. Journ. Sci. 45:105. 1846.

Eriophorum paucinervum (Engelm.) A. A. Eaton, in Bull. Torr. Club 25: 341. 1898.

Slender perennial with angled, scabrous (at least above) culms to 80 cm tall; leaves channeled throughout, to 15 cm long, 1.5 mm broad, subulate, the uppermost sheath shorter than the blade; involucral bract 1, channeled throughout, to 6 cm long, usually reddish-brown near its base; spikelets 2-7, on scrabrous peduncles to 2 cm long, the spikelets 1.2-1.7 cm long in flower, 2.0-3.0 cm long in fruit; scales greenish or reddish-brown, more or less obtuse; anthers 1-2 mm long; achenes 2.5-3.1 mm long, apiculate; bristles numerous, white.

Habitat.—Bogs.

Range.—Newfoundland to Saskatchewan, south to Minnesota, Illinois, and New Jersey.

Engelmann segregated this species as a variety of *E. gracile* with inconspicuous nerves on the scales. Eaton elevated Engelmann's variety to species rank, but the material on which it is based is identical with *E. tenellum.*

This species, which probably no longer grows in Illinois, was found a single time during the nineteenth century in a bog in Cass County. *Evers 34911* from Volo, Lake County, labeled *E. tenellum*, actually is *Rhynchospora alba.*

Specimen Examined.— Cass Co.: Beardstown, *Geyer s.n.* (ILL).

3. *Eriophorum angustifolium* Honck. Vergz. Gew. Teutschl. 153. 1782.

Eriophorum polystachion L. Sp. Pl. 52. 1753, nomen confusum.

Eriophorum angustifolium var. *majus* Schultz, Fl. Starg. Suppl. 5. 1819.

Eriophorum polystachion var. *elatius* Babington, Man. Brit. Bot. 333. 1843.

Rather robust, tufted perennial with angled, glabrous culms to 8.0 cm tall; leaves channeled in the upper half, flattened below, 3.5-7.5 mm wide, with scrabrous margins; involucral bracts 2-3, flattened below, more or less channeled above, purple near the base; spikelets 2-10, on glabrous peduncles to 5.5 cm long, the spikelets ovoid, 1-2 cm long in flower, 2.5-5.0 cm long in fruit; scales lead-colored to castaneous, acute; anthers 2.5-5.0 mm long; achenes 2.5-3.5 mm long, apiculate; bristles numerous, white.

Habitat.—Bogs.

Range.—Newfoundland to Alaska, south to Oregon, New Mexico, Illinois, and Massachusetts; Europe; Asia.

The Linnean binomial *E. polystachion*, long a source of confusion, has been rejected as a *nomen confusum.*

Our specimens, with a rather robust stature and with leaves 3.5-7.5 mm wide, have been distinguished as var. *majus.*

The glabrous peduncles, purple-based bracts, and large anthers differentiate this species from *E. viridicarinatum.*

This species, known from nine northern counties, is the only *Eriophorum* which has been collected in more than two counties.

Specimens Examined.—Boone Co.: 3 miles N. of Capron, *Fell & Fell f46339* (ILL, ISM). Cook Co.: 2 miles S. of Barrington, *Steyermark 63513* (ILL).

Kane Co.: Elgin, *Sherff 3055* (F). Lake Co.: Illinois Beach State Park, *Winterringer 10907* (ISM). Lee Co.: S. of Amboy, *V. Chase 11999* (F). McHenry Co.: McHenry, *Benke 4062* (F). Peoria Co.: Peoria, *Brendel s.n.* (ILL). Winnebago Co.: Fountaindale, *Bebb 5* (ISM). Woodford Co.: Upper Ferry, *McDonald s.n.* (ILL).

4. *Eriophorum viridicarinatum* (Engelm.) Fern. in Rhodora 7:89. 1905.
Eriophorum latifolium var. *viridicarinatum* Engelm. in Am. Journ. Sci. 46: 103. 1843.
Eriophorum polystachyon var. *latifolium* A. Gray, Man. Bot. 529. 1848.

Slender, tufted perennial with triangular, glabrous culms to 75 cm tall; leaves channeled at the apex, to 6 mm wide; involucral bracts 2-4, channeled only at the tip, green or pale brown at the base; spikelets (2-) 3-25, on puberulent peduncles to 6 cm long, the spikelets elliptic-ovoid, 6-10 mm long in flower, 15-30 mm long in fruit; scales green or occasionally lead-colored, sometimes mucronulate; anthers 1.0-1.3 mm long; achenes 2.0-3.5 mm long, apiculate; bristles numerous, cream.

Habitat.—Swamps and bogs.

Range. Labrador to Alaska, south to British Columbia, Wyoming, Iowa, and New York.

The usually green scales account for the derivation of the epithet, but specimens with lead-colored scales are known. These latter greatly resemble *E. angustifolium*.

Specimens Examined.—Lake Co.: Illinois Beach State Park, *Haynie s.n.* (F). Rock Island Co.: Port Byron, *Harper s.n.* (WIS).

5. *Eriophorum virginicum* L. Sp. Pl. 52. 1753.

Slender, but firm, perennial with glabrous culms to nearly a meter tall; leaves channeled only at the tip, to 4 mm wide; involucral bracts 2-5, spreading, channeled at the tip, to 10 cm long; spikelets up to 20, crowded in a glomerule, ellipsoid, 6-10 mm long in flower, up to 20 mm long in fruit; scales stramineous or green with brownish margins, acute, several-nerved; stamen 1; anther 1.2-1.5 mm long; achene 3-4 mm long; bristles tawny or white.

Habitat.—Bogs.

Range.—Labrador to Manitoba, south to Nebraska and Florida.

The several-nerved green scales, the single stamen, and the tawny bristles characterize this species. Specimens with white bristles, such as *Hill s.n.* from Long Lake, Lake County, have been designated *f. album* (Gray) Wieg.

Specimens Examined.—Lake Co.: Grant Township, *Hill 114.1908* (ILL); Volo bog, *McDougall 283* (ILL); Lake Villa, *Gleason & Shobe 117* (F), *254* (F); E. of Antioch, *Evers 8287* (ILLS).

IX. Rhynchospora

Rhynchospora is a cyperaceous genus readily recognized by the conspicuous style persistent on the achene in the form of a beak. This accounts for the common name of beaked rush. The presence of this persistent style relates *Rhynchospora* to *Bulbostylis*.

Vahl first segregated *Rhynchospora* as a genus in 1806, transferring several species originally described in *Schoenus*.

The first report of a species of *Rhynchospora* in Illinois was by Vasey in 1860 when he attributed *R. capillacea* from Lake County. Patterson listed five species from Illinois in 1876—*R. alba*, *R. capillacea*, *R. glomerata* (= *R. capitellata*), *R. corniculata*, and *R. cymosa* (=*R. globularis*). Bailey and Swayne added a sixth species (*R. glomerata*) in 1951, and Mohlenbrock, Ozment, and Folkerts reported *R. macrostachya* in 1962.

The most comprehensive treatment of *Rhynchospora* for North America was by Gale (1944). Gale's treatment has been followed by Fernald (1950) in the Eighth Edition of Gray's Manual.

Morphology of the Genus

The species of *Rhynchospora* are slender or robust perennials with bulbous bases. The culms may attain a height of 2 meters (*R. corniculata*). The species are invariably glabrous.

The leaves may be capillary or as broad as 20 mm. Occasionally the leaves are scabrerulous along the margins.

The inflorescence, which may be a meter long, is composed of glomerules of spikelets. The spikelets are usually a dark reddish-brown, except in *R. alba* where they are whitish or light brown. The spikelets may be either sessile or pedicellate. They may be as long as 2.8 cm (*R. macrostachya*). Lowermost scales are usually sterile, while the uppermost occasionally bear imperfect flowers. There are usually three stamens.

The achene may be lenticular, globose, or flattened (in *R. macrostachya*) and is crowned by a beak which is the persistent style-base (which distinguishes this genus from *Cladium*). The achenes may be smooth and lustrous or rugulose.

The beak ranges from 0.3-5.4 mm long. It may be smooth or serrulate. The bristles, which represent the perianth, are smooth, antrorsely hairy, or retrorsely hairy. They are 3-14 in number and may be longer or shorter than the achene.

Ecology and Geograhpy

All species of *Rhynchospora* in Illinois are limited to boggy, marshy, or swampy situations. None of the seven can be considered abundant, since *R. corniculata*, the most common one, is known only from seven counties.

The two robust species, *R. corniculata* and *R. macrostachya*, basically are southern in their American distribution and, hence, are limited in Illinois to the extreme southern counties. *Rhynchospora alba*, *R. capillacea*, and *R. globularis* are distinctly northern and are known only from the northeastern counties.

Rhynchospora capitellata and *R. glomerata*, which have a range throughout eastern United States, occur at both the northern and southern extremities of Illinois, even though they are very rare.

Systematic Treatment

Rhynchospora Vahl, Enum. 2:229. 1806.

Key to the Illinois Species of *Rhynchospora*

1. Leaves 6-20 mm broad; achene 4.7-5.5 mm long, 2.5-3.0 mm broad; beak 12-20 mm long.
   2. At least one of the usually 6 bristles longer than the achene.....1. *R. macrostachya*
   2. None of the usually 3-5 bristles longer than the achene.....2. *R. corniculata*
1. Leaves 0.3-6.0 mm (7.0 rarely in *R. glomerata*); achene 1.2-2.6 mm long, 0.8-1.6 mm broad; beak 0.3-1.8 mm long.
   3. Bristles antrorsely hairy, rarely smooth or entirely lacking; tubercle 0.3-0.6 mm high, broadly deltoid.....3. *R. globularis*
   3. Bristles retrorsely hairy, rarely smooth; tubercle 0.6-1.8 mm long, conical.
      4. Spikelets lanceoloid; bristles 3.6-4.3 mm long; leaves capillary, at most 0.4 mm broad.....4. *R. capillacea*
      4. Spikelets ovoid to lanceovoid; bristles 2.0-3.5 mm long (occasionally to 4.0 mm long in *R. glomerata*); leaves 0.5-7.0 mm broad.
         5. Achene with a conspicuous margin, smooth.
            6. Achene 1.2-1.4 mm wide, with broad shoulders; bristles 3-4 mm long.....5. *R. glomerata*
            6. Achene 0.8-1.2 mm wide, pyriform; bristles 2.0-2.8 mm long.....6. *R. capitellata*
         5. Achene emarginate, or nearly so, slightly rugulose.....7. *R. alba*

1. *Rhynchospora macrostachya* Torr. ex A. Gray, in Ann. Lyc. N. Y. 3:206. 1835.

Robust perennial with bulbous-thickened base; culms to 1 meter tall, glabrous; leaves 0.6-1.2 cm broad, glabrous, the sheaths glabrous; inflorescence 0.6-1.0 m long, stiffly ascending, the terminal glomerules sessile or on stalks to 4 mm long; spikelets 7-45 in a glomerule, reddish-brown, 1.5-2.8 cm long; scales elliptic-lanceolate, subacute; achenes obovoid, flattened on the faces, short-stipitate, 4.7-5.4 mm long, 2.5-3.0 mm broad; beak subulate, serrulate, 1.5-2.0 cm long, 1-2 mm broad at base; bristles (4-) 6, antrorsely hairy, at least some of them 1 cm long or longer.

Habitat.—Swampy woods and ditches.

Range.—Maine to Kansas, south to Texas and Florida.

This is the most recent species of *Rhynchospora* to be added to the Illinois flora. A single, small colony occurring in a swampy roadside ditch north of Pulaski represents the only Illinois station.

Much similarity exists between *R. macrostachya* and *R. corniculata*, but the latter is more robust (up to 2 meters tall) and has bristles which never exceed the achene. These two species comprice Section Calyptrostylis.

Specimen Examined.—Pulaski Co.: N. of Pulaski, *Mohlenbrock & Voigt 5742* (SIU).

2. *Rhynchospora corniculata* (Lam.) Gray, in Ann. Lyc. N. Y. 3:205. 1835.

Schoenus corniculatus Lam. Tabl. Encycl. 1:137. 1791.

Rhynchospora corniculata var. *interior* Fern. in Rhodora 20:140. 1918.

Robust perennial with swollen base; culm stout, erect, to nearly 2 m tall; leaves several, to 20 mm broad, with smooth or scabrerulous margins; inflorescence much branched, often nearly 1 m long; glomerules with 4-10 flowers; achenes (in our area) 4.7-5.5 mm long, 2.6-3.0 mm broad; beak 12-18 mm long, the base two-thirds to nearly equalling the width of the summit of the achene; bristles 3-5, shorter than the achene or with 1 bristle longer than the achene.

Fernald maintains that plants of the Mississippi Valley, because of their smaller achenes and enlarged beak base, should be segregated as var. *interior* Fern. Complete overlapping in both the length and the width of the achenes makes it impossible to separate these taxa. The ratio of beak base width to achene summit width follows a clinal gradient from the Coastal Plain up the Mississippi Valley and offers no possible point of separation.

Habitat.—Swamps and low roadside ditches.

Range.—Delaware to Missouri, south to Texas and Florida.

In Illinois, this species has been found in seven extreme southern counties. Its northernmost station is in a low roadside ditch one mile north of Howardton in Jackson County. A report of this species from Gallatin County could not be verified.

The first mention of this species from Illinois was by Patterson in 1876.

Specimens Examined.—Alexander Co.: E. of Olive Branch, *Winterringer 3453* (ILL, ISM). Jackson Co.: 4 miles S. of Gorham, *Winterringer 5555* (ISM). Johnson Co.: 1 mile W. of West Vienna, *Mohlenbrock 14212* (SIU). Pulaski Co.: 4 miles S. of Ullin, *Winterringer 10722* (ISM). Massac Co.: Mermet Lake, *Mohlenbrock s.n.* (SIU). Saline Co.: Cottonwood Pond, *Bailey & Swayne 2843* (ISM, SIU). Union Co.: Near Lick Creek, *Mohlenbrock s.n.* (SIU).

3. *Rhynchospora globularis* (Chapm.) Small, Man. S. E. Fl. 184. 1933.

Rhynchospora cymosa var. *globularis* Chapm. Fl. So. U. S. 525. 1860.

Rhynchospora globularis var. *recognita* Gale, in Rhodora 46:245. 1944.

Tufted perennial with slender, glabrous culms to 50 cm tall (in Illinois); leaves 2-5 mm long, the sheaths glabrous; inflorescence cymose, the terminal glomerules 5-10 mm broad; spikelets crowded 2.5-4.0 mm long; scales suborbicular, obtuse, occasionally mucronulate; achenes obovoid to suborbicular, transversely marked, frequently rugulose, 1.3-1.6 mm long, slightly narrower; beak merely deltoid, 0.3-0.6 mm long; bristles tiny, much shorter than the achenes, antrorsely hairy.

Habitat.—Moist, sandy soil.

Range.—New Jersey to Missouri, south to Texas and Florida; California; Central America; West Indies.

This is the only slender species of *Rhynchospora* in Illinois with antrorsely hairy bristles.

The Illinois specimen has been referred to as var. *recognita*. There may be some justification in recognizing this variant from var. *globularis*. Table I summarizes the differences.

TABLE I. Summary of major differences between *R. globularis* var. *globularis* and *R. globularis* var. *recognita*.

	var. *globularis*	var. *recognita*
Leaf Width	1-2 mm	2-5 mm
Glomerule Diameter	3-8 mm	5-10 mm
Achene Length	1-1.3 mm	1.3-1.6 mm
Beak Length	0.3 mm	0.3-0.6 mm

Only a single Illinois county is known.

Specimen Examined.—Kankakee Co.: 9 miles E. of St. Anne, *Schneider* 1656 (F).

4. *Rhynchospora capillacea* Torr. Fl. N. & Mid. States 55. 1823.

Rhynchospora capillacea var. *leviseta* E. J. Hill, in Am. Nat. 10:370. 1876.

Cespitose perennial with capillary culms to 40 cm tall; leaves filiform to linear, involute, to 0.4 mm wide; glomerules usually 2, the terminal with 2-10

spikelets, the lateral with 1-4 spikelets; spikelets sessile or nearly so; achenes oblong-obovoid, stipitate, 1.7-2.4 mm long, 0.9-1.4 mm broad (in our specimens); beak 0.8-1.5 mm long, the base about two-thirds as wide as the summit of the achene; bristles 6, longer than the achene, retrorsely hairy or smooth.

Habitat.—In bogs and marshes.

Range.—Newfoundland to Saskatchewan, south to Missouri and Virginia.

The slender spikelets and the capillary leaves distinguish this unusual Illinois species.

Specimens with glabrous bristles have been segregated as f. *leviseta.* These include *Swink 528* (ISM), *Bennett s.n.* (ILL), and *Hill 2925* (ILL), all from Illinois Beach State Park, Lake County.

The St. Clair County station, collected from by Brendel in the mid-nineteenth century, is probably extinct.

Specimens Examined.—Cook Co.: S. of Thornton, *Winterringer 16460* (ISM). Kane Co.: Elgin, *Fuller 9299a* (ISM). Lake Co.: Illinois Beach State Park, *Winterringer 8984* (ISM). St. Clair Co.: Without locality, *Brendel s.n.* (ILL).

5. *Rhynchospora glomerata* (L.) Vahl, Enum. 2:234. 1806.

Schoenus glomeratus L. Sp. Pl. 441. 1753.

Cespitose perennial with rather slender culms to 1.5 m tall; leaves linear to linear-lanceolate, 3-6 (-7) mm wide; spikelets subsessile, 4.5-6.5 mm long; achenes suborbicular, with broad "shoulders" and a prominent margin, lustrous, 1.5-1.8 mm long, 1.2-1.4 mm broad; beak 1.2-1.8 mm long, the base about one-half as broad as the summit of the achene; bristles usually 6, retrorsely hairy, 3-4 mm long.

Habitat.—Moist, often sandy soil.

Range.—New Jersey to Kansas, south to Texas and Florida.

Considerable difficulty exists in distinguishing this species from the scarcely separable *R. capitellata.* The characters employed in the key offer the only ways in identifying these species.

A specimen labeled *R. glomerata* from Thornton, Cook County (*Fuller 9035* [ISM], is *Cladium mariscoides.*

Only two authentic specimens of this species have been seen for Illinois.

Specimens Examined.—Kankakee Co.: Kankakee, *Hill 81.1871* (ILL). Pope Co.: Belle Smith Springs, *Swayne 1769* (ILL).

6. *Rhynchospora capitellata* (Michx.) Vahl, Enum. 2:235. 1806

Schoenus capitellatus Michx. Fl. Bor. Am. 1:36. 1803.

Cespitose perennial with slender culms rarely to 1.2 meters tall; leaves filiform to linear, 0.5-3.0 mm wide; terminal glomerule subsessile, the lateral pedunculate; spikelets 3-5 mm long; achenes pyriform, narrowly winged, 1.2-1.8 mm long, 0.8-1.2 mm broad; beak 1.0-1.5 mm long, the base about one-half as broad as the summit of the achene; bristles 5-6, retrorsely hairy or rarely glabrous, 2.0-2.8 mm long.

Habitat.—Moist soil.

Range.—Nova Scotia to Wisconsin, south to Texas and Florida; Oregon; California.

Smallness of all parts tends to distinguish this species from *R. glomerata.*

Although known from only five stations, this species is the most common of the slender *Rhynchosporas* in Illinois.

Graham 9396 (ISM), reported as *R. capitellata* by Evers and Winterringer (1960), is actually *Cladium mariscoides.*

Specimens Examined.—Cook Co.: West Pullman. *Hill 148* (F). Iroquois Co.: Near Beaverville, *Jones 18816* (ILL). Kane Co.: Elgin, *Benke 3669* (F). Kankakee Co.: W. of Kankakee, *Sherff 1656* (ILL). Pope Co.: N. of Herod, *Ahles 4686* (ISM).

7. *Rhynchospora alba* (L.) Vahl, Enum. 2:229. 1806.

Schoenus albus L. Sp. Pl. 44. 1753.

Cespitose perennial with very slender culms to 55 (-70) cm tall; leaves filiform to linear, 0.5-2.5 mm wide; glomerules whitish or light brown, the terminal one 5-15 mm broad, the lateral two somewhat smaller; spikelets sessile; achenes obovoid to pyriform, stipitate, slightly rugulose, lustrous, 1.5-2.0 mm long, the base about one-half as broad as the summit of the achene; beak elongate-triangular, 0.6-1.2 mm long, 1.2-1.8 mm broad; bristles (in our specimens) usually 10-14, 2.4-3.0 mm long, retrorsely hairy.

Habitat.—Sphagnum bogs.

Range.—Newfoundland to Alaska, south to California, Illinois, and Georgia; Puerto Rico; Europe; Asia.

Probably the only extant stations for this species in Illinois are in sphagnum bogs at Cedar Lake in Lake County and Maple Lake in Cook County. The Peoria County station known to Brendel during the latter part of the nineteenth century doubtlessly has been destroyed.

Cedar Lake is indeed a remarkable area which features a sphagnum bog

and several exceptionally rare vascular plants for Illinois. Numbered among these are *Carex trisperma, Carex viridula, Eriophorum virginicum, Nuphar variegatum, Sarracenia purpurea, Drosera rotundifolia, Sorbus aucuparia, Vaccinium myrtilloides, Aster longifolius,* and *Bidens beckii.*

Specimens Examined.—Cook Co.: Maple Lake, *Winterringer 12313* (ISM). Lake Co.: Lake Villa, *Gleason & Shobe 137* (F). Peoria Co.: Peoria, *Brendel s.n.* (ILL).

X. Cladium

Only a single species of the twig rush occurs in Illinois. It closely resembles species of *Rhynchospora,* but may be differentiated by its lack of a beak on the achene.

1. *Cladium mariscoides* (Muhl.) Torr. in Ann. Lyc. N. Y. 3:372. 1836.

Schoenus mariscoides Muhl. Gram. 4. 1817.

Stoloniferous perennial with a triangular culm to nearly 1 m tall; leaves channeled. 1-3 mm wide, scabrerulous on the margins; inflorescence paniculate, to 30 cm long; spikelets in clusters of 3-10, some pedunculate, others sessile; lowest scales sterile, the median ones staminate, the terminal one perfect; stamens 2; style usually 2-cleft; bristles 0; achene mitriform, truncate at base, apiculate at apex, 1.3-1.8 mm long.

Habitat.—Swamps and bogs.

Range.—Newfoundland to Saskatchewan, south to Minnesota, Illinois, and Florida.

There is a striking resemblance between this species and *Rhynchospora glomerata.* This latter species, however, has a beaked achene and bristles.

The first record of this species in Illinois is a collection from Chicago, Cook County, in 1860, by Scammon.

Specimens Examined. — Cook Co.: Thornton, *Fuller 9035* (ISM). Lake Co.: Illinois Beach State Park, *Winterringer 15183* (ISM). McHenry Co.: Ringwood, *Vasey s. n.* (ILLS).

XI. Scleria

This distinctive genus was named by Bergius in 1765. The first Illinois record was by Mead (1846) from Hancock County. *Scleria* stands well-apart from other cyperaceous genera because of its unisexual flowers, the disk-supported achene, and the white, bony achene.

Core's magnificent work (1936) on this genus has made the identification of the species relatively simple.

Morphology of the Genus

The Illinois species of *Scleria* are small annuals or slender to coarse perennials from rhizomes. The triangular culms may attain a height of nearly one meter. They are glabrous or scabrous.

The flat leaves range from 1-9 mm wide. They and their sheaths are glabrous or variously pubescent.

The inflorescence is terminal and axillary, pedunculate or sessile. The involucral bracts, which generally exceed the inflorescence, are glabrous or pubescent. Both staminate and pistillate spikelets occur. The 1-flowered pistillate spikelets are usually distributed among clusters of staminate spikelets. The lowermost scales are sterile. Perianth bristles are absent. There are 1-3 stamens. The style is 3-cleft.

The lustrous, white, bony achene, which is the most conspicuous feature of the genus, is smooth, papillose, pitted, or wrinkled. It is situated upon an hypogynium, or the hypogynium may be obsolete (*S. verticellata*). The hypogynium is pebbled or bears tubercles. The characters of the achene and hypogynium are important in distinguishing species.

Systematic Treatment

Scleria Berg. in Kongl. Acad. Sv. Handl. 26:142. 1765.

Key to the Illinois Species of *Scleria*

1. Achene smooth; tubercles of hypogynium none; coarse perennial .. ..1. *S. triglomerata*
1. Achene papillose, pitted, or wrinkled; tubercles of hypogynium 0, 6, or 9; slender perennial or annual.
   2. Achene papillose; tubercles of hypogynium 6 or 9; perennial ....2. *S. pauciflora*
   2. Achene pitted or wrinkled; tubercles none; annual.

3. Achene pitted; hypogynium 3-lobed; inflorescence closely paniculate; achene 1.8-2.2 mm long .....3. *S. reticularis*
3. Achene wrinkled; hypogynium absent; inflorescence verticillate; achene 1.5 mm long .. ..4. *S. verticillata*

1. *Scleria triglomerata* Michx. Fl. Bor. Am. 2:168. 1803.

Rather coarse perennial from an elongated rhizome; culms triangular, glabrous, sometimes nearly 1 m tall; leaves 4-9 mm broad, glabrous or puberulent on the nerves below, scabrous, the sheaths and ligules glabrous or puberulent; inflorescences usually terminal and lateral, the bracts elongate; achenes subglobose to ovoid, smooth, lustrous, white, 2.0-2.5 mm high and broad; hypogynium shallowly 3-lobed, minutely pebbled, without tubercles.

Habitat.—Moist or dry open woods.

Range.—Vermont to Minnesota, south to Texas and Florida.

This is the largest as well as the most common species of *Scleria* in Illinois, although it is restricted to the northern half of the State. It is our only species with a smooth achene.

Two other species with smooth achenes which have been collected in neighboring states may eventually be found in Illinois. *Scleria nitida*, which lacks tubercles but has an achene longer than broad, is a species of dry, upland woods of Kentucky and Missouri. *Scleria oligantha*, with 8 or 9 tubercles between the achene and the hypogynium, is a species of rich hardwood forests of Indiana, Kentucky, and Missouri.

Specimens Examined.—Cass Co.: E. of Beardstown, *Rexroat 4159* (ISM). Cook Co.: N. of Jefferson Park, *Moffatt s.n.* (ILL). Fulton Co.: N. of Anderson Lake, *Rexroat 5211* (ISM). Henderson Co.: Oquawka, *Patterson s.n.* (F). Iroquois Co.: Near Beaverville, *Jones 18818* (ILL). Kankakee Co.: SE. of St. Anne, *Fuller 8930* (ILL, ISM). Lake Co.: N. of Waukegan, *Gates 2772* (ILL). Lee Co.: Without locality, *Long 753* (ILL). McHenry Co.: Ringwood, *Vasey s.n.* (ILL). McLean Co.: Without locality, *Brendel s.n.* (ILL). Peoria Co.: Near Princeville, *V. Chase 1252* (ILL). Will Co.: E. of Braidwood, *Schneider s.n.* (ILLS). Winnebago Co.: 2 miles W. of South Beloit, *Fell & Fell F47-148* (ISM).

2. *Scleria pauciflora* Muhl. ex Willd. Sp. Pl. 4:318. 1805.

Slender perennial from forking rhizome; culms triangular, scabrous on the angles, glabrous or pilose; inflorescence of mostly small terminal fascicles or sometimes pedunculate axillary fascicles; bracts much longer than the inflorescence; achene globose, white, papillose, 1.5-2.0 mm high and broad; hypogynium with 6 or 9 tubercles.

Two usually separable varieties may be recognized in Illinois.

a. Culms and leaves glabrous or sparsely hirtellous ....2a. *S. pauciflora var. pauciflora*
a. Culms and leaves densely pilose ....2b. *S. pauciflora var. caroliniana*

2a. *Scleria pauciflora* Muhl. ex Willd. var. *pauciflora*

Habitat.—Dry soil, in woods or on bluffs.

Range.—New Jersey to Kansas, south to Texas and Florida; West Indies.

The typical variety is more common than var. *caroliniana* in Illinois. At Giant City State Park, where it is locally abundant, it occurs on exposed sandstone ledges with *Isanthus brachiatus*, *Cunila origanoides*, *Agrostis elliottiana*, *Hypericum drummondii*, and others.

Specimens Examined.—Hardin Co.: 2½ miles W. of Elizabethtown, *Ahles 6206* (ILL, ISM). Henry Co.: Rock River Hills, *Dobbs s.n.* (ILLS). Johnson Co.: Without locality, *Brendel s.n.* (ILL). Union Co.: Giant City State Park, *Mohlenbrock 9214* (SIU).

2b. *Scleria pauciflora* Muhl. ex Willd. var. *caroliniana* (Willd.) Wood, Am. Bot. & Florist 368. 1871.

Scleria caroliniana Willd. Sp. Pl. 4:318. 1805.

This uncommon variety has a more eastern range in the United States than var. *pauciflora*. Only a single specimen is known from Illinois.

Specimen Examined.—Lee Co.: Without locality, *Long 792* (ILL).

3. *Scleria reticularis* Michx. Fl. Bor. Am. 2:167. 1803.

Small annual with slender, erect, glabrous culms to 50 cm tall; leaves 1-4 mm wide, glabrous; inflorescence composed of a crowded terminal panicle up to 3 cm long and lateral fascicles of spikelets on very short peduncles; bracts exceeding the inflorescence; achenes mostly obovoid, occasionally globose, 1.8-2.2 mm long, about as broad, olive-brown, glabrous with a regular pattern of shallow pits running transversely.

Habitat.—Sandy shore of pond.

Range.—Massachusetts to Delaware; South Carolina to Florida; Illinois; Indiana; Mexico.

The olive-brown achenes, annual habit with paniculate inflorescence, and transverse rows of pits on the achene serve to distinguish this species.

This is the latest species of *Scleria* to be added to the Illinois flora, having been found by Rexroat in 1959. Core has determined our material.

Aside from the Illinois station and a station in northwestern Indiana, this species is found only along the eastern seaboard and in Mexico.

Specimen Examined.—Cass Co.: W. of Virginia, *Rexroat 5351* (ISM).

4. *Scleria verticillata* Muhl. ex Willd. Sp. Pl. 4:317. 1805.

Small annual with very slender, glabrous, triangular culms to 50 cm tall; leaves up to 2 mm wide, the sheaths glabrous or pilose; inflorescence fascicled in the axils of small bracts, composed of several sessile spikelets; achenes globose, apiculate, 1.5 mm long and broad, white, transversely ridged; hypogynium none.

Habitat.—Bogs and marshes.

Range.—Massachusetts to Minnesota, south to Texas and Florida.

This is the only species of *Scleria* in Illinois with a verticillate inflorescence and without a hypogynium.

Only the Mason County specimen cited below has been collected in the last quarter of a century.

Specimens Examined.—Kane Co.: Elgin, *Benke 3674* (F). Lake Co.: Illinois Beach State Park, *Gates 3210* (F). Mason Co.: SE. of Havana, *Rexroat 4220* (ISM). Peoria Co.: Peoria, *McDonald s.n.* (ILL). Will Co.: Troy, *Hill 30.-1911* (ILL). Woodford Co.: Beyond upper ferry, *McDonald s.n.* (ILL).

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Manuscript received October 7, 1965.

THE FUNK FOREST NATURAL AREA, McLEAN COUNTY, ILLINOIS: WOODY VEGETATION AND ECOLOGICAL TRENDS

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ABSTRACT. — The composition of the Funk Forest Natural Area is transitional between the oak-hickory forests, found largely on uplands along streams, and the more mesophytic mixed stands of the "Prairie Groves" in central Illinois. In 1963 the stand consisted of 135 stems per acre (above 3 inches in diameter at breast height) with a basal area of 118 square feet, and included 40 woody species. Sugar maple was the leading dominant, followed closely by white oak. Sugar maple appeared to be increasing in the stand and comprised about half of the total number of seedlings and one-third of the small saplings. Mortality of elm and the veteran oak trees has enhanced the regeneration of sugar maple.

The 60-acre Funk Forest Natural Area is located in the W½, SW¼, S19, T21, R1E, 3rd PM (Longitude 89° 09′ W; Latitude 40° 21′ N), McLean County, Illinois. The woodland is transitional between the kind of forest that developed on uplands along watercourses and those found as isolated "Prairie Groves" in central Illinois. It was acquired by the University of Illinois in 1950 and has been maintained as a natural area for instructional and research purposes. This paper, third in a series concerning the woody vegetation of University-owned natural areas (Boggess, 1964; Boggess and Bailey, 1964), is concerned with results of an inventory completed in 1963.

The only previously reported work in the woodland is that of Calef (1953a, 1953b) which presented data from a strip-transect survey of the woody vegetation, a check list of vascular plants, and a discussion of the avian and other vertebrate populations.

Description of Area

The natural area and surrounding woodlands are remnants of a forested area that, based on soil characteristics (Odell, 1957), may have occupied as much as four to five square miles on broken lands of the LeRoy Moraine. Much of the original forest was cleared for agriculture, although several hundred acres of woodland remain today. However, most of this timbered area has been cut over and heavily grazed, and stand conditions scarcely resemble those in the protected natural area.

The most conspicuous topographic features are associated with Timber Creek, which flows westward across the area about 500 to 600 feet from the south end (Figure 1). The south creek bank rises sharply and forms a bluff up to 40 feet tall. The rolling upland between the bluff and the south boundary is cut by four deeply

Figure 1.—Distribution of sugar maple, sugar maple-mixed hardwood, mixed hardwood, and mixed hardwood-pawpaw types in Funk Forest Natural Area, McLean County, Illinois.

dissected gullies which drain into the creek. The north bank is five to six feet above the stream bed. The immediately adjacent area is flat, with many depressions, for 500 to 600 feet, and then rises in gently sloping topography to the north boundary. Maximum relief over the area is about 50 feet.

A detailed soil survey has not been made, but the soils range from deep terrace soils in the level area north of the stream to well-developed Gray-Brown Podzolic soils on the uplands. The soils have developed in about 60 inches of loess over morainal material of Wisconsin age and are related to the Birkbeck-Reesville Association. The well-developed forest soils have silt loam A horizons from 10 to 12 inches deep, overlying silty clay to clay loam B horizons with subangular blocky structure. In three soil pits on the area, calcareous till was encountered at depths of 66, 78, and 80 inches. Organic matter varied from about 5 percent in the A1 to less than 0.25 percent in the B2 horizons, while pH ranged from 6.0 to 4.5, respectively, for the same horizons.

Methods of Study

All woody plants 2.6 inches and above in diameter at breast height were measured to the nearest 1/10 inch and tallied by species. Dead-standing and dead-down trees were also measured and identified when possible. Records were kept separately for each of the 96 blocks (50 meters square), into which the area was permanently divided prior to the inventory.

Four sets of nested, circular quadrats, 1/100 and 1/1,000 acre in size, were randomly located in each block. The 1- and 2-inch diameter classes were tallied on the larger and seedlings on the smaller plots. The seedlings were sep-

arated into those under 1 foot in height, and those over 1 foot in height but less than 0.6 inch in diameter.

Results

A total of 40 woody species were identified, 12 of which were understory trees or shrubs. These species, along with their density and frequency by size classes, are shown in Table 1. The species symbols used here will serve to identify species in subsequent tables and figures. An additional breakdown into broad diameter classes, by basal area and number of trees per acre for the 15 leading species, is shown in Table 2. Also shown are percentage of total number of trees and basal area, average diameter, and importance value index (IVI). As used here, importance value index is the sum of the relative density

$$\frac{\text{Number individuals of a species}}{\text{Number individuals all species}} \times 100$$

and of the relative dominance

$$\frac{\text{Basal area of a species}}{\text{Total basal area of all species}} \times 100$$

This modification of the original IVI (Curtis and McIntosh, 1951), was used by McIntosh (1957) in his study of York Woods in southern Wisconsin.

Sugar maple was the dominant species on 59 of the 96 blocks in the woodland (Table 3). It comprised almost one-third of the total number of trees and one-fourth of the stand basal area. Importance value index averaged 57.9 and ranged as high as 148 on a single block (maximum possible value, 200). Frequency of occurrence varied from 94 percent for trees above 3 inches in diameter to 64 percent for seedlings and 50 percent for small saplings (1- and 2-inch diameters). Sugar maple averaged 11.7 inches in diameter, and the largest individual tree had a d.b.h. of 33 inches.

White oak ranked second in IVI and was the leading dominant on 15 blocks and second in importance on 32 blocks. However, its importance was related to the size of individual trees rather than tree numbers. Average diameter was 31.9 inches, and more than three-fourths of the white oaks had diameters greater than 24 inches. Basal area was about equal to that of sugar maple, but with only one-sixth the number of trees. Small saplings were rare, as not a single 1- or 2-inch diameter white oak was tallied on the 1/100-acre plots. Seedlings were poorly distributed, as indicated by the frequency of 12 percent, and most of them occurred within, or immediately adjacent to, the mixed hardwood type.

Slippery elm and American elm were the third and fourth ranking species and were well distributed throughout the woodland. Both species were most prevalent in the smaller diameter classes, as most of the larger trees have died from phloem necrosis and the Dutch elm disease. However, a few large elms were still alive at the time of the inventory. There were considerably more slippery elm than American elm seedlings, but the number of small saplings was about the same for both species.

Basswood, ranking fifth in importance, was scattered throughout the stand, and about half of the trees were in the 3- to 6-inch diameter classes. The distribution of seedlings and small sapling was spotty, as indicated by the low frequency of occurrence.

Hackberry and bur oak were sixth and seventh in importance and were leading dominants on 3 blocks and 4 blocks, respectively. Bur oak is notable because of the large size of individual trees, ranging up to 59 inches in diameter. Almost half of the bur oaks were above 36 inches in diameter, but general distribution was poor. Bur oak seedlings and saplings were essentially nonexistent. Hackberry was found on 75 percent of the plots. The average diameter was 10.7 inches, and about three-fourths of the trees were less than 12 inches in diameter.

The ashes—white, green, and blue—ranked eighth, tenth, and fourteenth, respectively. White ash and green ash were best distributed in the woodland with frequencies of 70 and 61 percent, respectively, compared with 28 percent for blue ash. White ash and blue ash were best represented in the seedling class, but frequency of occurrence was low for all species.

The remaining species listed in Table 3 have small importance values and were not leading dominants on any of the blocks. Red oak, as in the case of bur oak, occurred as scattered, fairly large trees, with an average diameter of 24.5 inches.

Pawpaw, hawthorn, ironwood, and blue beech, all understory species, made

TABLE 1.—Density Per Acre and Frequency of Woody Species by Height or Diameter Class. (The species symbol will be used to identify species in subsequent tables and figures.)

Scientific Name	Common Name	Symbol	Height Class				Diameter Class			
			Density			Frequency %	Density 1″ & 2″	Frequency %	Density 3″ +	Frequency %
			<1′	>1′ <0.6″ d.b.h.	Total					
Acer saccharum Marsh	Sugar maple	SM	2,698	2,117	4,815	63.8	167	50.3	42.18	94
Ulmus americana L.	American elm	AE	190	102	292	13.3	30	18.7	16.12	94
Ulmus rubra Muhl.	Slippery elm	SE	966	445	1,411	40.1	26	13.3	14.34	97
Tilia americana L.	Linden, basswood	L	81	57	138	0.5	16	4.9	11.43	92
Celtis occidentalis L.	Hackberry	H	130	117	247	16.7	15	10.2	6.55	75
Quercus alba L.	White oak	WO	557	96	653	12.5	.....	.....	5.33	80
Fraxinus americana L.	White ash	WA	107	75	182	10.9	4	3.4	4.07	70
Carya glabra (Mill.) Sweet	Pignut hickory	PH	8	.....	8	0.8	0.3	0.3	3.35	42
Carya cordiformis (Wang) K. Koch	Bitternut hickory	BH	65	104	169	10.9	3	3.1	3.33	68
Fraxinus pennsylvanica Marsh	Green ash	GA	18	3	21	1.6	0.3	0.3	2.15	61
Quercus rubra L.	Red oak	RO	203	39	242	10.2	.....	.....	1.57	55
Quercus macrocarpa Michx.	Bur oak	BO	5	.....	5	0.5	.....	.....	1.22	25
Carya ovata (Mill.) K. Koch	Shagbark hickory	SH	.....	.....	.....	.....	.....	.....	0.93	25
Fraxinus quadrangulata Michx.	Blue ash	BA	93	21	114	4.2	0.8	0.8	0.85	28
Acer saccharinum L.	Silver maple	SiM	.....	.....	.....	.....	0.3	0.3	0.80	7
Juglans nigra L.	Black walnut	BW	.....	.....	.....	.....	0.3	0.3	0.76	28
Acer negundo L.	Boxelder	BE	.....	.....	.....	.....	.....	.....	0.54	10
Gymnocladus dioica (L.) K. Koch	Kentucky coffee tree	CT	13	18	31	1.8	0.8	0.8	0.38	15
Platanus occidentalis L.	Sycamore	S	.....	.....	.....	.....	.....	.....	0.33	11
Quercus velutina Lam.	Black oak	Bl.O	.....	.....	.....	.....	.....	.....	0.24	9
Prunus serotina Ehrh.	Black cherry	BC	16	8	24	1.3	0.3	0.3	0.23	6
Carya tomentosa Nutt.	Mockernut hickory	MH	5	.....	5	0.5	.....	.....	0.19	4
Juglans cinerea L.	Butternut	BT	.....	.....	.....	.....	.....	.....	0.11	5

TABLE 1.—Continued.

Scientific Name	Common Name	Symbol	Height Class				Diameter Class			
			Density			Frequency %	Density 1″ & 2″	Frequency %	Density 3″ +	Frequency %
			<1′	>1′ <0.6″ d.b.h.	Total					
Quercus Muhlenbergii Engelm.	Chinquapin oak	CO	28		28	1.6			0.10	4
Gleditsia triacanthos L.	Honey locust	HL							0.04	2
Quercus fallax E. J. Palmer	Q. macrocarpa x Q. Muhlenbergii	X							0.04	2
Maclura pomifera (Raf.) Schneid.	Osage orange	OO							0.03	2
Carya laciniosa (Michx. f.) Loud.	Shellbark hickory	Sh.H							0.02	1
Asimina triloba (L.) Dunal	Pawpaw	PP	195	468	663	30.2	187	42.9	7.64	45
Ostrya virginiana (Mill.) K. Koch	Ironwood	IW	3	39	42	2.1	17	9.1	6.39	57
Carpinus caroliniana Walt.	Blue beech	BB					1	0.8	1.61	26
Crataegus spp.	Hawthorn	HT		5	5	0.5	3	1.8	1.01	21
Cercis canadensis L.	Redbud	RB	5	5	10	1.0	0.3	0.3	0.34	17
Morus rubra L.	Mulberry	M		5	5	0.3	0.8	0.8	0.24	14
Euonymus atropurpureus Jacq.	Wahoo	W	13	10	23	0.8	5	2.9	0.03	2
Ribes missouriense Nutt.	Common gooseberry	GB	52	68	120	1.8				
Staphylea trifolia L.	Bladdernut	BN	210	339	549	4.9	11	3.9		
Zanthoxylum americanum Mill.	Prickly ash	PA		3	3	0.3				
Ptelea trifoliata L.	Hop tree	PT					1	0.3		
Corylus americana Walt.	Hazelnut	HN	5	10	15	0.8	4	0.5		
Total			5,666	4,154	9,820		494.2		134.49	

TABLE 2.—Number of Trees and Basal Area Per Acre by Diameter Class, Percentage of Total Trees and Basal Area, Average Diameter, and Importance Value Index for Leading Dominants.

Species	Diameter Class (inches)										Total		Percentage of Total		Av. Diam. In.	Impor. Value Index
	3–6		7–12		13–24		25–36		37+							
	No.	BA	No.	BA	No.	BA	No.	BA	No.	BA	No.	BA	No.	BA		
SM	13.74	1.465	14.54	7.241	13.26	20.182	0.64	2.561	.....	.....	42.18	31.449	31.36	26.58	11.7	57.94
WO	0.11	0.016	0.22	0.119	0.91	1.860	2.71	14.850	1.38	12.807	5.33	29.652	3.96	25.06	31.9	29.02
SE	8.21	0.761	3.13	1.429	2.50	4.370	0.48	2.141	0.02	0.149	14.34	8.850	10.66	7.48	10.6	18.14
AE	10.52	1.029	3.71	1.659	1.81	2.628	0.04	0.221	0.04	0.351	16.12	5.888	11.99	4.98	8.1	16.97
L	5.76	0.576	3.25	1.508	2.40	3.153	0.02	0.074	.....	.....	11.43	5.311	8.50	4.49	9.2	12.99
H	3.12	0.328	1.94	0.843	1.30	2.171	0.19	0.799	.....	.....	6.55	4.141	4.87	3.50	10.7	8.37
BO	0.05	0.003	0.08	0.041	0.28	0.610	0.33	1.670	0.48	5.217	1.22	7.541	0.91	6.37	33.4	7.28
WA	0.46	0.039	1.38	0.759	1.99	3.226	0.24	0.790	.....	.....	4.07	4.814	3.03	4.07	14.8	7.10
RO	0.06	0.010	0.17	0.081	0.57	1.190	0.74	3.521	0.03	0.236	1.57	5.038	1.17	4.26	24.5	5.43
GA	0.12	0.010	0.46	0.268	1.37	2.322	0.20	0.762	.....	.....	2.15	3.362	1.60	2.84	16.9	4.44
BH	0.89	0.113	1.50	0.683	0.89	1.258	0.05	0.176	.....	.....	3.33	2.230	2.48	1.88	10.7	4.36
PH	1.62	0.195	1.27	0.598	0.46	0.672	.....	.....	.....	.....	3.35	1.465	2.49	1.24	8.9	3.73
SH	0.17	0.031	0.36	0.175	0.31	0.418	0.09	0.408	.....	.....	0.93	1.032	0.69	0.87	14.1	1.56
BA	0.27	0.037	0.34	0.182	0.18	0.309	0.06	0.266	.....	.....	0.85	0.794	0.63	0.67	12.7	1.30
BW	0.23	0.027	0.08	0.025	0.45	0.799	.....	.....	.....	.....	0.76	0.851	0.57	0.72	14.3	1.29
Others	17.51	1.317	1.85	0.693	0.60	1.052	0.21	1.011	0.14	1.823	20.31	5.896	15.10	5.01	.....	20.11
Total	62.84	5.957	34.28	16.304	29.28	46.220	6.00	29.250	2.09	20.583	134.49	118.314	.....	.....	.....	.....

TABLE 3.—Importance Value Index Rank, by Numbers of Blocks, for Leading Dominants.

Species	IVI Rank				
	1st	2nd	3rd	4th	Below
	Number of Blocks				
SM	59	13	3	2	13
WO	15	32	7	5	18
L	6	3	8	11	60
AE	5	12	18	19	36
BO	4	4	6	5	5
SE	3	18	26	15	31
H	3	6	9	5	49
BH	1	.....	3	6	55
WA	....	4	7	10	46
RO	....	2	6	7	38
GA	....	1	2	5	21
PH	....	1	....	5	34
SH	....	.....	1	....	23
BA	....	.....	....	....	27

up 12.4 percent of the total number of trees. However, they occurred largely in the 3- and 4-inch diameter classes and thus comprised only 1.3 percent of the total basal area. Pawpaw was the only one of these species with an appreciable amount of reproduction. Its significance as a type indicator will be discussed later.

Four broad cover types were recognized, based on the IVI values of the 15 leading species (Table 4) on each of the 96 blocks. Blocks of similar composition were grouped together, and characteristic species groups were defined for different IVI levels of sugar maple. These natural groupings provided a basis for the cover-type descriptions given below. Cover-type boundaries, as shown in Figure 1, were smoothed by field observation.

Sugar maple.—This type occurred on 12.5 acres, or 21.1 percent of the area, and included stands where sugar maple accounted for over 50 percent of the total importance value. Average IVI of sugar maple in this type was 105.3. White oak and slippery elm were the most consistent associates and had higher importance values than any other secondary species. American elm, basswood, and white ash had high frequencies, while hackberry, green ash, red oak, bitternut hickory, and pignut hickory were present about 50 percent of the time. All eight of these species had low importance values. "Other" species were represented a very small portion

TABLE 4.—Average IVI of Leading Dominants Accordings to Cover Type.

Species	Cover Type			
	Sugar maple	Sugar maple-mixed hardwood	Mixed hardwood-pawpaw	Mixed hardwood
SM	105.3	81.6	25.3	35.0
WO	26.2	31.7	30.6	44.6
SE	15.3	17.1	16.7	30.1
AE	5.0	16.1	20.6	25.1
L	3.9	9.0	19.7	14.3
H	1.8	5.1	15.5	1.1
BO	0	2.1	15.9	0
WA	4.1	8.7	5.1	15.8
RO	5.5	4.6	5.6	8.5
GA	3.3	4.7	4.8	4.7
BH	2.1	3.1	7.7	1.7
PH	1.3	2.8	2.2	15.5
SH	0.8	1.5	0.8	5.5
BA	0.4	1.2	2.0	0
BW	0.5	1.5	1.7	0.4
Others	3.3	12.7	30.6	22.2

of the time and showed no consistent association.

Sugar maple-mixed hardwood.—This type included 15.8 acres, or 26.6 percent, of the woodland. Sugar maple comprised from 30 to 50 percent of the stand, and its IVI averaged 81.6. White oak was the second most important species and occupied this position on half of the blocks in the type. Slippery elm, American elm, and basswood were well distributed over the area as species of tertiary importance. Hackberry, white ash, green ash, red oak, and bitternut hickory all had low importance values but occurred on more than 50 percent of the plots. The understory trees—ironwood, blue beech, and pawpaw—occurred in varying densities throughout the type.

Mixed hardwood-pawpaw understory.—This type, the largest in the woodland, occurred on 22.5 acres, or 37.9 percent, of the area. Sugar maple, white oak, and American elm shared importance equally, but proportions of each varied considerably over the area. Hackberry, basswood, blue ash, and bitternut hickory had their highest importance values in this type. Over 90 percent of the bur oaks were found here, and this species was the leading dominant on four blocks. "Other" species were quite heterogeneous in mixture, with individuals of Kentucky coffee tree, chinquapin oak, and hawthorn well distributed throughout. Understory trees were quite prominent, with over 92 percent of the pawpaw and 71 percent of the blue beech occurring in this area. Since pawpaw occurred in large numbers and was essentially limited to this area, it was considered as a type indicator and used as a part of the type name. The bottomland species—sycamore, soft maple, and box elder—were present along Timber Creek. However, because so many other species were also present, no bottomland type was differentiated.

Mixed hardwood.—This type occurred in a band of 7.0 acres, or 11.8 percent of the area, at the northern end of the woodland. It is separated from the preceding mixed hardwood type by the increased IVIs of more xeric species. White oak and sugar maple ranked as the most important species. While white oak had its highest IVI here, it alternated with sugar maple as the leading dominant on 10 of the blocks in the area. Slippery elm was the leading dominant on the remaining block. Slippery elm, American elm, white ash, pignut hickory, red oak, and shagbark hickory also had highest IVIs in this type. "Other" species consisted largely of black oak, mockernut hickory, and ironwood. The first two of these were limited almost entirely to this part of the woodland.

Discussion

The interrelationships between the various species are shown in Table 5, where the average IVI and constancy percentage of the 15 leading species is given for those blocks on which a given species was the leading dominant, e.g., had the highest IVI (Curtis and McIntosh, 1951). For example, on blocks where sugar maple was the leading dominant, its average IVI was 80.6. On these same blocks, white oak IVI averaged 27.6; slippery elm, 18.3; American elm, 13.3; etc. Constancy percentage is not used here in the normal sense, but instead expresses in percentage the number of blocks on which a given species occurred with another species as the leading dominant. Thus, white oak occurred on 89.8 percent (constancy percentage = 89.8) of the blocks on which sugar maple was the leading dominant.

The relationship between sugar maple and white oak is of particular interest, since white oak did not occur in either Brownfield or Trelease Woods (Boggess and Bailey, 1964; Boggess, 1964). Also in his study of York Woods, in a similar prairie-forest border situation, McIntosh (1957) found that sugar maple and white oak were significantly disassociated. This is clearly not the case in our study, since white oak occupied the second IVI position where sugar maple was dominant and vice versa. The high constancy percent-

TABLE 5.—Average Importance Value and Constancy Percentage of Tree Species on Blocks With a Given Species as the Leading Dominant.

Species		Leading Dominant							
		SM	WO	SE	AE	L	H	BO	BH
SM	IVI	80.6	34.4	20.9	18.7	6.0	14.4	11.2	4.1
	C%	100.0	100.0	100.0	100.0	50.0	66.7	50.0	100.0
WO	IVI	27.6	66.0	15.7	11.0	3.3	6.7	0.3	0
	C%	89.8	100.0	66.7	80.0	16.6	33.3	25.0	0
SE	IVI	18.3	23.5	37.9	17.8	3.3	9.7	10.6	10.0
	C%	100.0	93.3	100.0	100.0	66.7	100.0	100.0	100.0
AE	IVI	13.3	23.3	20.3	34.6	13.9	20.6	21.8	20.0
	C%	91.5	100.0	100.0	100.0	100.0	100.0	75.0	100.0
L	IVI	8.5	8.4	16.2	19.0	59.4	12.1	19.1	8.4
	C%	86.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0
H	IVI	4.3	4.4	12.9	16.6	24.6	34.5	22.7	9.9
	C%	64.4	93.3	66.7	100.0	100.0	100.0	100.0	100.0
BO	IVI	1.6	0	17.2	12.5	18.9	13.9	69.3	34.3
	C%	10.2	0	66.7	60.0	83.3	100.0	100.0	100.0
WA	IVI	6.8	15.2	6.8	3.4	0.3	0	3.5	4.0
	C%	72.9	100.0	33.3	60.0	16.6	0	75.0	100.0
RO	IVI	5.9	6.3	4.8	4.4	2.6	0	9.6	2.9
	C%	54.2	66.7	66.7	60.0	33.3	0	75.0	100.0
GA	IVI	4.6	7.3	1.8	3.0	1.2	3.8	1.6	3.4
	C%	62.7	73.3	66.7	60.0	16.6	66.7	50.0	100.0
BH	IVI	3.1	3.2	13.0	11.9	5.9	4.5	7.8	35.4
	C%	61.0	60.0	66.7	100.0	83.3	100.0	100.0	100.0
PH	IVI	3.3	9.9	3.6	0.3	0.2	0	0	0
	C%	45.8	66.7	33.3	20.0	16.6	0	0	0
SH	IVI	1.3	3.1	6.7	0	0.2	0	0	0
	C%	28.8	33.3	33.3	0	16.6	0	0	0
BA	IVI	1.1	0.8	5.1	3.1	0.8	1.0	0.5	0
	C%	27.1	13.3	33.3	80.0	33.3	33.3	25.0	0
BW	IVI	1.0	0.7	1.6	0.6	5.3	3.9	0	2.5
	C%	22.0	20.0	33.3	20.0	83.3	100.0	0	100.0
Others	IVI	13.6	18.0	12.1	21.0	43.1	50.6	47.0	41.8
	C%	88.1	93.3	100.0	100.0	100.0	100.0	100.0	100.0

age (C%) also indicates a close relationship between the two species. However, we recognize that "constancy" loses some of its significance because of the relatively large block size used as a sampling unit.

Sugar maple and white oak represent two distinct age classes. This is emphasized in Figure 2, where smooth curves of the basal area by diameter class are shown for each of the two species in comparison with that for all species combined. The bimodal character of the total basal area curve, with the predominance of white oak in diameter classes greater than 30 inches, suggests that this species was a "pioneer" in respect to most of the others. It seems logical to assume that sugar maple has perhaps been increasing steadily during the past century. The large number of sugar maple seedlings, 4,815 per acre, suggests a continuation of this trend.

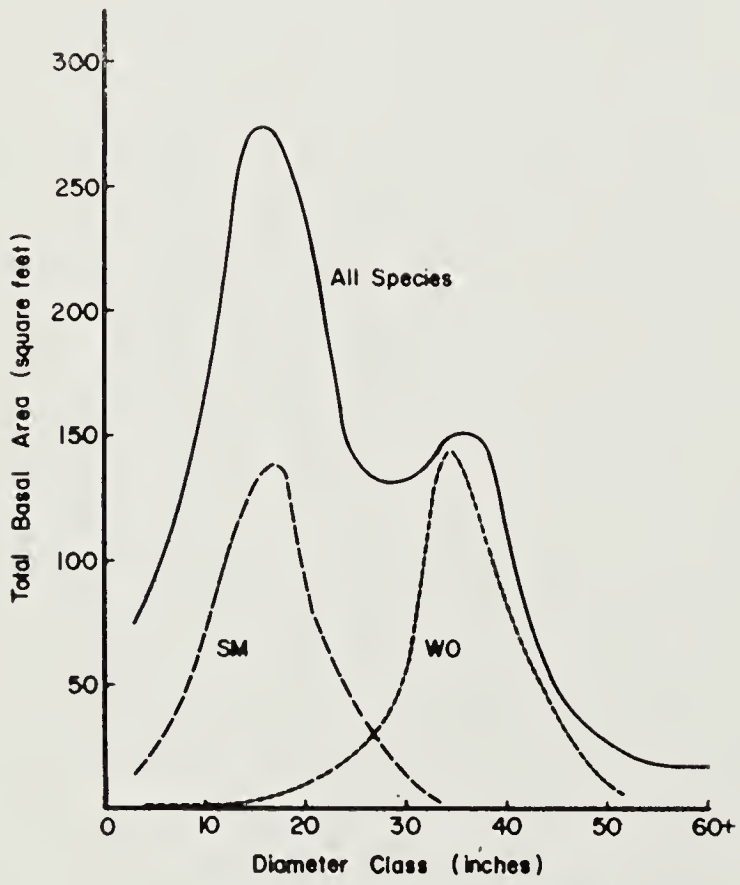

Figure 2.—Smooth curves of basal area by diameter class for sugar maple, white oak, and all species combined in Funk Forest Natural Area.

Certainly the position of sugar maple has been enhanced by mortality of the large oak and elm trees which has occurred in the past 10 to 15 years. Mortality during this period, as indicated by dead-standing and dead-down trees, amounted to 897 trees, or 1,269 square feet of basal area, for the entire woodland (15.1 trees and 21.4 square feet per acre). Elms accounted for 70 percent and 62 percent of these totals, respectively, and mortality was well distributed throughout all diameter classes. In contrast, oak mortality was largely among the veteran trees. For instance, 37 out of 45 dead white oaks were 24 inches or above in diameter.

Mortality has affected the status of sugar maple in the stand in two ways. First, the gradual death of the large oaks has created openings in the canopy over a long period of years. The quick response of the highly tolerant sugar maple seedlings and small saplings to such release is well known and perhaps is responsible for the good distribution of sugar maple in all diameter classes under 30 inches. Secondly, the recent catastrophic mortality of elm, particularly American elm, has not only created additional canopy openings through the death of large trees, but has also removed a large number of trees from the smaller diameter classes that were competing with the sugar maples. These effects are illustrated by comparing our data with those of Calef (1953a), recognizing that perhaps only the ratios given are valid, since we do not know the

errors of estimate for Calef's partial sample. In 1953 there was a 1 to 1 ratio of elm and sugar maple, for trees above 3 inches in diameter, but elm outnumbered maple by a ratio of 3 to 2 in the 3- to 7-inch diameter classes. By 1963 the ratio was 4 to 3, in favor of sugar maple for all trees, and 5 to 4 in the same order for the 3- to 7-inch diameter trees. Thus, the ratio of saplings has been completely reversed during the past decade. It is significant that Calef did not mention any unusual elm mortality in his 1953 report. This, coupled with observations of others who have frequently visited the woodland, indicates that the elm mortality has largely occurred since 1953.

The future status of white oak, and the other oaks as well, appears to be one of decreasing importance as the inevitable mortality of the veteran trees continues. There are only 20 white oaks less than 13 inches in diameter in the woodland, and three-fourths of these are in the mixed hardwood type which occupies about 12 percent of the woodland area. White oak seedlings are also most prevalent in the same type, where they have a frequency of 45 percent, compared with 12.5 percent for the remainder of the woodland. However, the white oak seedlings are not developing into saplings, as evidenced by the lack of 1-, 2-, and 3-inch diameter trees. While the white oak seedlings may persist for a number of years, their chances of growing into the sapling stage are slight because of competition from the much larger number of highly tolerant sugar maple seedlings.

The effect of past use on the present composition of the woodland is difficult to determine. Calef (1953a) mentioned the presence of numerous black walnut stumps from trees that had been logged. The area was also grazed to some extent prior to its acquisition by the University. The population of maple seedlings has "exploded" during the past few years and may well increase for some years to come. This prediction is based on data from Brownfield Woods (Boggess and Bailey, 1964), where the number of maple seedlings is about twice as great as in the Funk Forest Natural Area. These two woodlands are topographically similar, but Brownfield Woods has been completely protected from use about twice as long as the Funk Forest Natural Area.

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Manuscript received April 25, 1965.

THE VASCULAR FLORA OF THE MISSISSIPPI PALISADES STATE PARK, CARROLL COUNTY, ILLINOIS

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ABSTRACT. — An annotated catalog of the vascular flora of the Mississippi Polisades State Park, Carroll County, Illinois, containing 569 species was compiled from data collected in the field and from five state institutional herbaria. One hundred and ninety-eight species are listed that have not been previously recorded for Carroll County.

The Mississippi Palisades State Park, composed of 1560 acres, is located in northwestern Illinois, north of Savanna, Carroll County (Fig. 1). The park, which lies in the southern part of the "Driftless Area", is principally composed of a greatly dissected section of the eastern bluff of the Mississippi River. Massive cliffs of Niagaran dolomite, the underlying bedrock, with vertical columns of rock eroded from the face are conspicuous features along the western border of the park. The local relief is approximately 280 feet. Drainage is to the west to the Mississippi River. The uplands and steep slopes are covered with loess soils varying from a few inches to more than 30 feet in depth. They have weakly developed profiles and little accumulation of clay in the subsoil. The buff bases are covered with talus and silt soils. The flood plains of the large valleys and the Mississippi River have alluvial soils of silt and silty-clay loams.

The climatic data, taken from Page (1949), are from a weather station located at Mount Carroll nine miles east of the park. The average January temperature is 20.9°F., the average July temperature is 73.3°F., and the average annual temperature is 48.1°F. The total annual precipitation is 34.20 inches with June, the wettest month, receiving 4.55 inches. The total annual snowfall is 32.3 inches with the largest amount, 8.3 inches, being received in January. The average date of the last killing frost in spring is May 8th and the average date of the first killing frost in autumn is October 5th, resulting in a frost-free period averaging 150 days in length. Prevailing winds in winter are from the northwest and from the southwest in summer.

VEGETATION

The Mississippi Palisades State Park has a number of diverse habitats with a rich and correspondingly diverse vegetation. The vegetation of the uplands is composed primarily of an oak woods with small to extensive prairie openings. The oak woods tend to be mesic and rich in species of trees, although almost pure stands of *Quercus alba* do occur. Much *Betula papyrifera* occurs in

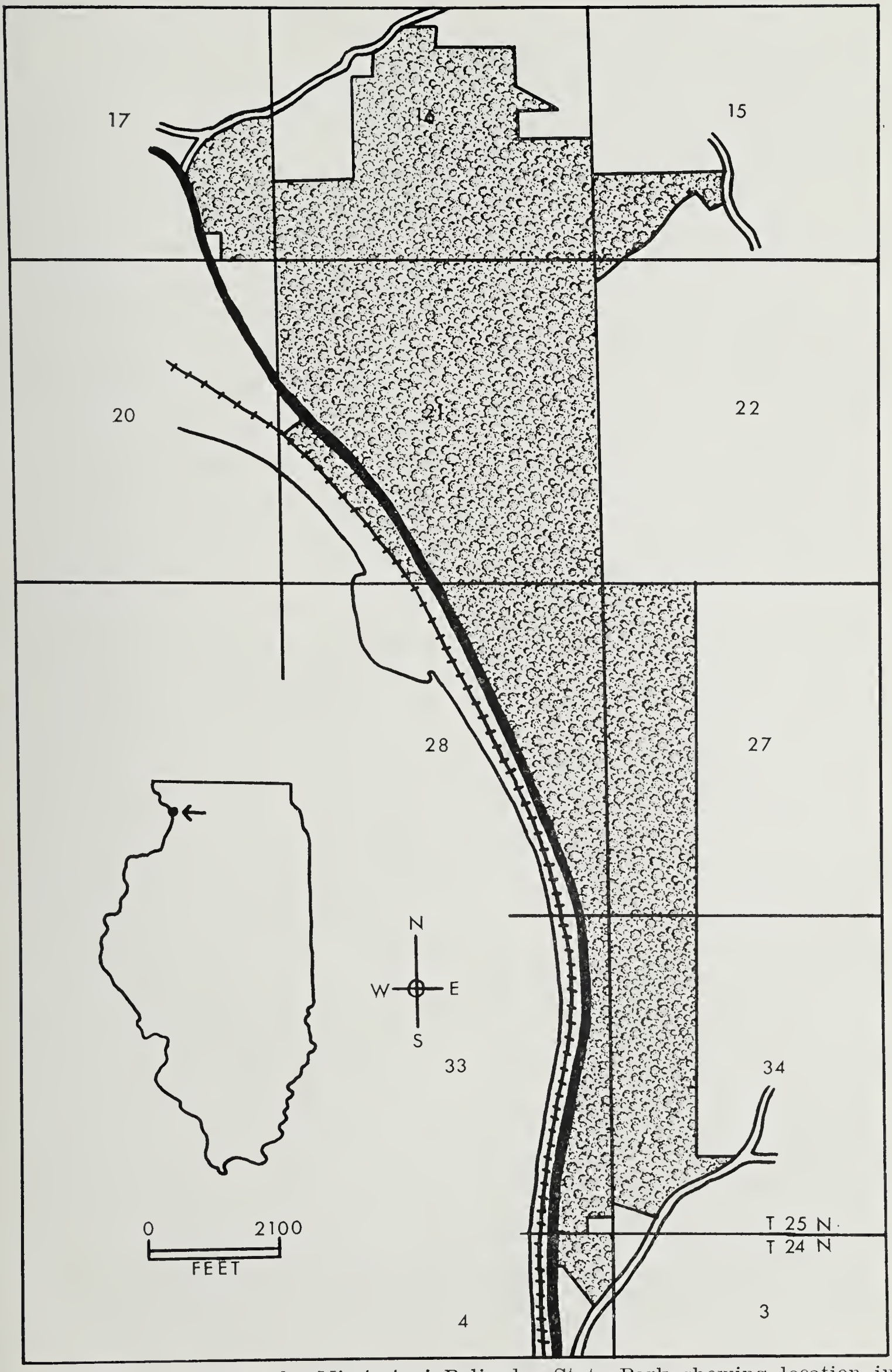

FIGURE 1.—Map of the Mississippi Palisades State Park showing location in Illinois and extent of coverage in Washington (T.25 N.–R.3 E.) and Savanna (T.24 N.–R.3 E.) Townships.

the uplands even in the dryer regions where *Juniperus virginiana* grows. The moist slopes and ravines contain a more mesic vegetation with *Acer saccharum* and *Tilia americana* as the dominant tree species. A rich herb and shrub layer is found throughout the forested regions. The prairie openings are dominated by *Andropogon furcatus* and *Sorghastrum nutans* and contain a large number of characteristic prairie forbs. In the northern part of the park are large expanses of land which were formerly cultivated and to which the native prairie vegetation is now returning. On the edge of the exposed western bluffs is a more xeric vegetation. Here *Juniperus virginiana* is abundant and several hill prairies occur with *Andropogon scoparius* and *Bouteloua curtipendula* as the dominant grasses. On the dry calcareous cliffs are growing *Solidago hispida, Cheilanthes feei, Arabis lyrata, Pellaea glabella, Campanula intercedens,* and on one high exposed cliff, *Opuntia rafinesquii.* On the shaded cliffs and rocky slopes are found *Dodecatheon amethystinum* and *Synthyris bullii* growing with numerous species of more common vascular plants. At the base of the slopes, where deep silt deposits occur, the woods grades into a lowland woods also rich in species. Here *Platanus occidentalis* and *Betula nigra* are common trees. Between the railroad track and the Mississippi River is a lowland meadow rich in herbs, scattered clumps of *Salix interior,* and an *Acer saccharinum-Betula nigra* lowland woods. In the meadow *Carex* spp. and *Spartina pectinata* are common with the latter often reaching over six feet in height. The aquatic habitats are also rich in species as four species of Lemnaceae and six species of Potamogetonaceae grow in the shallow water in the park. Large beds of *Nelumbo lutea* occur in the river and *Nymphaea tuberosa* is common in one pond.

Annotated Catalog of the Vascular Flora

The following catalog includes 569 species of native and naturalized vascular plants that are known to grow in the Mississippi Palisades State Park according to the investigator's studies conducted during the summers of 1962-1965. Also listed are 198 species not previously reported as occurring in Carroll County. This catalog has been annotated to give information on the habitats and relative abundance in the park for each species collected by the investigator, followed by the investigator's collection number(s). These specimens are deposited in the herbarium at Western Illinois University, Macomb. Specimens of species collected by other botanists and examined by the investigator are cited by the collector's name, collection number, and an abbreviation of the name of the institution in which they are deposited. Specimens were examined from the Illinois Natural History Survey (ILLS), the Illinois State Museum (ISM), Western Illinois University (WIU), Southern Illinois University (SIU), and the University of Illinois (ILL). The species proceeded by an asterisk (*) are those which have not been previously reported as occurring in Carroll County. These records are based on data compiled by Jones and

Fuller (1955) and Winterringer and Evers (1960).

The order of the plant families and the nomenclature is that of Jones (1963).

Equisetaceae Rich.

Equisetum arvense L. Frequent in moist sandy soil; 165, 685.
**Equisetum fluviatile* L. Local in wet ground; 2268.
**Equisetum hyemale* L. Local in wet ground; 617.

Ophioglossaceae Presl

Botrychium virginianum (L.) Sw. Frequent in rich woods; 248.

Osmundaceae R.Br.

Osmunda claytoniana L. Frequent in rich woods; 164.

Polypodiaceae S. F. Gray

Adiantum pedatum L. Frequent in rich woods; 58.
Athyrium angustum (Willd.) Presl. Frequent in rich woods; 124, 162, 235.
Athyrium thelypterioides (Michx.) Desv. Local in rich woods; 236.
Camptosorus rhizophyllus (L.) Link. Frequent on moist limestone rocks in woods; 68.
Cheilanthes feei Moore. Frequent on dry exposed limestone cliffs; 129.
Cystopteris bulbifera (L.) Bernh. Frequent on moist rocks in rich woods; 86, 128, 187.
Cystopteris fragilis (L.) Bernh. Common in rich woods; 220.
Dryopteris hexagonoptera (Michx.) C. Chr. Local in rich woods; 705.
Dryopteris spinulosa (O. F. Muell.) Watt. Frequent in rich woods; 163, 1057.
Onoclea sensibilis L. Frequent in and along the edge of woods; 102.
Pellaea glabella Mett. Frequent on dry exposed limestone cliffs; 88.
**Polystichum acrostichoides* (Michx.) Schott. Local in rich woods; 1056.
Pteridium latiusculum (Desv.) Hieron. Frequent in and along the edge of woods; 251.
Woodsia obtusa (Spreng.) Torr. Local on moist rocks in rich woods; 2688.

Taxaceae Lindl.

Taxus canadensis Marsh. One small stand on edge of cliff; 247.

Pinaceae Lindl.

**Pinus nigra* Arnold. One mature stand planted with *Pinus sylvestris* but not reproducing spontaneously; 230.
Pinus strobus L. One small stand on open bluff top, possibly planted; 111.
**Pinus sylvestris* L. One mature stand planted with *Pinus nigra* but not reproducing spontaneously; 229.

Cupressaceae Horan.

Juniperus virginiana L. Locally abundant on exposed bluffs; 90.

Ranunculaceae Juss.

**Actaea alba* (L.) Mill. Frequent in rich woods; 250.
**Actaea rubra* (Ait.) Willd. Frequent in rich woods; 2676.
Anemone canadensis L. Frequent in open woods; 833.
Anemone cylindrica A. Gray. R. A. Evers 12736 (ILLS).
Anemone virginiana L. Frequent in open woods; 144, 668, 1062.
Aquilegia canadensis L. Frequent on rock outcrops in woods; 669.
Hepatica acutiloba DC. Common in rich woods; 621, 794.
Isopyrum biternatum (Raf.) Torr & Gray. Locally abundant in woods; 639.
Ranunculus abortivus L. Frequent in open ground; 632.
**Ranunculus pennsylvanicus* L.f. Local in wet ground; 940.
Ranunculus septentrionalis Poir. Frequent in rich woods; 650, 788.
Thalictrum dioicum L. Frequent in rich woods; 2777.
**Thalictrum revolutum* DC. Local along the edge of woods; 2762.

Nymphaeaceae DC.

**Nymphaea tuberosa* Paine. Locally abundant in shallow water; 920.

Nelumbonaceae Lindl.

**Nelumbo lutea* (Willd.) Pers. Abundant in Mississippi River; 970.

Ceratophyllaceae A. Gray

**Ceratophyllum demersum* L. Common in shallow water; 917.

Podophyllaceae DC.

Caulophyllum thalictroides (L.) Michx. Frequent in rich woods; 648.
Podophyllum peltatum L. Frequent in open woods; 981.

Menispermaceae DC.

**Menispermum canadense* L. Common in woods; 234.

Violaceae DC.

**Viola bernardii* Greene. Local on exposed bluff top; 2088.
**Viola eriocarpa* Schw. Frequent in rich woods; 652.
**Viola missouriensis* Greene. Local in open grounds; 2502.
**Viola pedatifida* Don. Frequent in hill prairies and open woods; 2087.
**Viola priceana* Pollard. Local in open ground; 2501.
Viola rugulosa Greene. Locally abundant in woods; 200, 624, 638.
Viola sororia Willd. Frequent in woods; 637, 787.

Cistaceae Horan.

Helianthemum bicknellii Fern. Local in hill prairies; 856.
Lechea villosa Ell. Local in hill prairies; 784, 867.

Papaveraceae B. Juss.

Sanguinaria canadensis L. Common in rich woods; 620, 721.

Fumariaceae DC.

Dicentra cucullaria (L.) Bernh. Common in rich woods; 622, 792.

Cruciferae B. Juss.

**Alliaria officinalis* Andrz. Locally abundant along the edge of woods; 84.
Arabis canadensis L. Local in woods; 84-1.
Arabis lyrata L. Common on limestone outcrops and cliffs; 195, 626, 629.
**Barbarea vulgaris* R. Br. Local in waste ground; 880.
**Brassica juncea* (L.) Cosson. Local in waste ground; 478.
**Brassica nigra* (L.) Koch. Local in waste ground; 225.
**Dentaria laciniata* Muhl. Frequent in rich woods; 786.
**Descurainia sophia* (L.) Webb. Local in waste ground; 2779.
**Draba reptans* (Lam.) Fern. Local on dry hillsides; 623.
**Erucastrum gallicum* (Willd.) O. E. Schulz. Local in waste ground; 2778.
**Erysimum cheiranthoides* L. Local in waste ground; 2780.
**Erysimum inconspicuum* (Wats.) MacM. Local in waste ground; 2795.
Lepidium virginicum L. Frequent in open ground; 470.
**Rorippa islandica* (Oeder) Borbas. Local in wet ground; 2695.
**Rorippa sylvestris* (L.) Besser. Local in wet ground; 838, 841.
**Sisymbrium officinale* (L.) Scop. Local in waste grounds; 477.

Hypericaceae Lindl.

**Hypericum canadense* L. Local in wet ground; 982.
**Hypericum perforatum* L. Frequent in open woods and prairies; 153.
Hypericum punctatum Lam. Frequent in open woods and prairies; 149, 159, 935.

Tiliaceae Juss.

Tilia americana L. Common in woods; 60.

Malvaceae Necker

**Hibiscus militaris* Cav. Local in wet ground; 807.

Caryophyllaceae Reichenb.

**Cerastium vulgatum* L. Frequent in open ground; 805, 961.
**Silene antirrhina* L. Local in waste ground; 2661.
**Silene nivea* (Nutt.) Otth. Local in rich woods; 2756.
**Stellaria aquatica* (L.) Scop. Local in open ground; 491.

Portulacaceae Reichenb.

**Claytonia virginica* L. Locally abundant in rich woods; 640.
Portulaca oleracea L. Local in waste ground; 2673.

Chenopodiaceae Dum.

Chenopodium album L. Frequent in waste ground; 152, 1073.
**Chenopodium boscianum* Moq. Local in open woods; 2797.
Chenopodium hybridum L. Local in open woods and waste ground; 197.
Kochia scoparia (L.) Roth. Local in waste ground; 467.
**Salsola pestifer* A. Nels. Local in waste ground; 2665.

Amaranthaceae J. St. Hil.

Acnida altissima Riddell. Frequent in wet ground; 811.
**Amaranthus retroflexus* L. Frequent in waste ground; 476.

Nyctaginaceae Lindl.

Mirabilis nyctaginea (Michx.) MacM. Local in open ground; 466.

Polygonaceae Lindl.

Polygonum aviculare L. Frequent in waste ground; 473.

Polygonum convolvulus L. Local in waste ground; 489.
**Polygonum erectum* L. Local in waste ground; 471, 672.
Polygonum pennsylvanicum L. Frequent in waste ground; 492, 806.
**Polygonum persicaria* L. Frequent in waste ground; 137, 177.
Polygonum punctatum Ell. Frequent in waste ground; 804, 1058.
**Polygonum scandens* L. Local in waste ground; 780.
**Polygonum virginianum* L. Local in rich woods; 496.
Rumex acetosella L. Frequent in open ground; 683, 879.
**Rumex altissimus* Wood. Local in open ground; 840, 966.
Rumex crispus L. Local in open ground; 2671.

Rutaceae Juss.

Ptelea trifoliata L. Local on rocky, wooded slopes; 465.
Zanthoxylum americanum Mill. Frequent in open woods; 65.

Geraniaceae J. St. Hil.

Geranium maculatum L. Frequent in rich woods; 831.

Oxalidaceae Lindl.

Oxalis stricta L. Common in open ground; 113.
Oxalis violacea L. Local in open woods and hill prairies; 651.

Balsaminaceae Lindl.

**Impatiens biflora* Walt. Locally abundant in wet ground; 189.
Impatiens pallida Nutt. Locally abundant in wet ground; 239.

Polygalaceae Reichenb.

**Polygala sanguinea* L. Local in open meadow; 2691.
Polygala senega L. R. A. Evers 10672 (ILLS).
Polygala verticillata L. R. A. Evers 61509 (ILLS).

Euphorbiaceae J. St. Hil.

Acalypha rhomboidea Raf. Frequent in woods; 474, 810, 817.
Acalypha virginica L. R. A. Evers 61484 (ILLS).
Chamaesyce maculata (L.) Small. Frequent in waste ground; 469.
Chamaesyce supina (Raf.) Moldenke. Frequent in waste ground; 475.
Euphorbia corollata L. Common in prairies and open woods; 123, 141.
**Euphorbia marginata* Pursh. Local in open ground; 2727.
Poinsettia cyathophora (Murr.) Small. Local in open ground; 2719.
Poinsettia dentata (Michx.) Small. Local in open ground; 487.

Celastraceae Lindl.

Celastrus orbiculatus Thunb. Frequent in open woods; 710.
Celastrus scandens L. Frequent in open woods; 213.
Euonymus atropurpureus Jacq. Local on rocky, wooded slopes; 776.

Staphyleaceae (DC.) Lindl.

Staphylea trifolia L. Local on rocky, wooded slopes; 56, 647.

Anacardiaceae Lindl.

Rhus arenaria (Greene) G. N. Jones. Local on rocky slopes; 646, 828, 2678.
Rhus aromatica Ait. Local on rocky slopes; 2684.
Rhus glabra L. Common along the edge of woods; 80.
Rhus radicans L. Common in woods; 233.

Aceraceae J. St. Hil.

Acer negundo L. Frequent in lowland woods; 55.
Acer saccharinum L. Common in lowland woods; 510.
**Acer saccharum* Marsh. Common in moist, wooded ravines; 59.

Rhamnaceae R. Br.

Ceanothus americanus L. Local in open woods and prairies; 94, 680.
Rhamnus cathartica L. Local along the edge of woods; 87, 515.
**Rhamnus frangula* L. Local along the edge of woods; 2686.

Vitaceae Lindl.

Parthenocissus quinquefolia (L.) Planch. Common in woods; 101.
Vitis riparia Michx. Local in wet ground; 2790.
Vitis vulpina L. Frequent in woods; 99, 100, 829-A.

Rosaceae Juss.

Agrimonia pubescens Wallr. Frequent in woods; 122, 709.
Amelanchier spicata (Lam.) K. Koch. Local on exposed bluff tops; 214.
Aruncus dioicus (Walt.) Fern. Frequent in woods; 125.
**Crataegus crusgalli* L. Local in open woods; 97.

**Crataegus margaretta* Ashe. Along the edge of woods; 2752.
Fragaria americana (Porter) Britt. Local in open woods; 658.
**Fragaria virginiana* Duch. Frequent in open woods; 799, 974.
Geum canadense Jacq. Frequent in woods; 161.
Malus ioensis (Wood) Britt. Local in and along the edge of open woods; 228.
**Malus pumila* Mill. Persisting from cultivation and occasionally established along the borders of woods; 168.
Physocarpus opulifolius (L.) Maxim. Local on rocky, wooded slopes; 514.
Potentilla arguta Pursh. Frequent in prairies; 875.
Potentilla monspeliensis L. Frequent in prairies; 158, 965.
Potentilla recta L. Frequent in prairies and open ground; 154, 684.
Potentilla simplex Michx. Local in open ground; 679.
Prunus americana Marsh. Frequent along the edge of woods; 641, 706.
Prunus lanata (Sudw.) Mack. & Bush. R. M. Myers *s.n.* (WIU).
Prunus serotina Ehrh. Frequent in woods; 93.
Prunus virginiana L. Frequent along the edge of woods; 92, 593.
Pyrus communis L. R. A. Evers 10677 (ILLS).
Rosa carolina L. Frequent along the edge of woods and in prairies; 870.
**Rosa setigera* Michx. Local along the edge of woods; 2687.
Rosa suffulta Greene. R. A. Evers 24467 (ILLS).
Rubus allegheniensis Porter. Common along the edge and in open woods; 107.
Rubus flagellaris Willd. Local in open ground; 947.
**Rubus occidentalis* L. Frequent in and along the edge of woods; 66, 223.
Rubus odoratus L. G. D. Fuller 10525 (ISM).

Leguminosae P. F. Gmel.

Amorpha canescens Pursh. Frequent in hill prairies; 134.
Amorpha fruticosa L. Locally abundant near water; 83.
**Amphicarpa comosa* (L.) G. Don. Common in woods; 610.
**Apios americana* Medic. Locally abundant in wet ground; 818.
Astragalus canadensis L. Local in open woods; 871.
Baptisia leucantha T. & G. Frequent along the edge of woods and in prairies; 675.
Cassia fasciculata Michx. Locally abundant in open ground; 166.
Crotolaria sagittalis L. R. A. Evers 28206 (ILLS).
Desmodium canadense (L.) DC. Frequent in prairies; 138, 992.
Desmodium glabellum (Michx.) DC. Local in open woods; 2717.
Desmodium glutinosum (Muhl.) Wood. Common in rich woods; 109.
Desmodium illinoense A. Gray. Common in prairies; 139.
**Desmodium longifolium* (T. & G.) Smyth. Local in open woods; 169, 989.
Gleditsia triacanthos L. Local along the edge of woods; 110.
Gymnocladus dioicus (L.) K. Koch. Local in woods; 45.
Lespedeza capitata Michx. Common in prairies; 448.
**Lespedeza cuneata* (Dum.-Cours.) G. Don. Locally abundant along the edge of woods and in prairies where apparently planted; 607.
Medicago lupulina L. Frequent in waste ground; 2781.
Medicago sativa L. Local in open ground; 2666.
Melilotus alba Desr. Frequent in open ground; 75.
Melilotus officinalis (L.) Lam. R. M. Myers *s.n.* (WIU).
Petalostemum candidum (Willd.). Local in hill prairies; 243.
Petalostemum purpureum (Vent.) Rydb. Frequent in hill prairies; 135.
Strophostyles helvola (L.) Britt. Local in prairies and open woods; 451, 946.
Strophostyles leiosperma (T. & G.) Piper. R. A. Evers 28207 (ILLS).
**Trifolium agrarium* L. R. M. Myers *s.n.* (WIU).
Trifolium dubium Sibth. R. A. Evers 12707 (ILLS).
Trifolium hybridum L. Frequent in open ground; 1059.
Trifolium pratense L. Frequent in open ground; 155.
Trifolium procumbens L. Frequent in open ground; 89, 683, 924.
Trifolium repens L. Frequent in open ground; 224.

Hydrangeaceae Dumort.

**Hydrangea arborescens* L. Persistent from cultivation near the site of old dwelling; 2767.

Grossulariaceae Dumort.

Ribes americanum Mill. Local in rich woods; 2694.
Ribes cynosbati L. Frequent in open woods; 181, 631.
Ribes missouriense Nutt. Frequent in open woods; 642.

Hamamelidaceae Lindl.

**Hamamelis virginiana* L. Local in rich woods; 61.

Platanaceae Lindl.

Platanus occidentalis L. Frequent in lowland forest; 513.

Crassulaceae DC.

**Sedum sarmentosum* Bunge. Local along the edge of woods where probably introduced; 2799.
**Sedum triphyllum* (Haw.) S. F. Gray. Persistent from cultivation near the site of old dwellings; 2798.

Penthoraceae Van Tieghem

Penthorum sedoides L. Frequent in wet ground; 950.

Saxifragaceae DC.

Heuchera richardsonii R. Br. R. A. Evers 64168 (ILLS).
Mitella diphylla L. Frequent in rich woods; 643.

Fagaceae A. Br.

**Castanea dentata* (Marsh.) Borkh. Possibly persistent from cultivation in rich wooded ravine; 2716.
Quercus alba L. Common in woods; 81.
**Quercus ellipsoidalis* E. J. Hill. Local in woods; 704.
Quercus macrocarpa Michx. Frequent in open woods; 211.
Quercus muhlenbergii Engelm. Local on exposed bluff tops; 703, 827.
Quercus rubra L. Common in woods; 198, 215.
Quercus velutina Lam. Common in woods; 96, 179.

Betulaceae Agardh

Betula nigra L. Common in lowland woods; 116.
Betula papyrifera Marsh. Common in woods; 151.
Corylus americana Walt. Frequent along the edge of woods; 108, 160.
Ostrya virginiana (Mill.) K. Koch. Common in woods; 57.

Juglandaceae Lindl.

Carya cordiformis (Wang.) K. Koch. Frequent in open woods; 184.
Carya ovata (Mill.) K. Koch. Frequent in open woods; 193.
Juglans cinerea L. Local in woods; 98.
Juglans nigra L. Frequent in woods; 2698.

Salicaceae Lindl.

Populus deltoides Marsh. Frequent in lowland woods; 48.
Populus grandidentata Michx. Frequent along the edge of woods; 103.
Populus tremuloides Michx. Frequent along the edge of woods; 115.
**Salix amygdaloides* Anders. Local in wet grounds; 500, 937.
Salix humilis Marsh. Local in prairies; 245, 865.
Salix interior Rowlee. Frequent in wet ground; 936.
**Salix nigra* Marsh. Frequent in wet ground; 501.
Salix rigida Muhl. G. N. Jones 16365 (ISM).
**Salix sericea* Marsh. Local in wet ground; 627.

Ulmaceae Mirb.

Celtis occidentalis L. Local in lowland woods; 53.
Ulmus americana L. Frequent in woods; 114.
**Ulmus rubra* Muhl. Frequent in woods; 43.

Moraceae Lindl.

**Morus alba* L. Local along the edge of woods; 54.
Morus rubra L. Local along the edge of woods; 64.
Morus tatarica L. Local along the edge of woods; 2510.

Cannabinaceae Lindl.

Cannabis sativa L. Local in open ground; 173.
**Humulus americanus* Nutt. Local along the edge of woods; 2715.

Urticaceae Reichenb.

**Boehmeria cylindrica* (L.) Sw. Frequent in wet ground; 809.
**Laportea canadensis* (L.) Gaud. Frequent in moist woods; 2680.
**Parietaria pennsylvanica* Muhl. Frequent in woods; 2697.
**Pilea pumila* (L.) A. Gray. Frequent in moist woods; 708.
Urtica gracilis Ait. Frequent in moist woods and waste ground; 1065.

Lythraceae Lindl.

**Ammannia coccinea* Rottb. Local in moist ground; 2794.

Lythrum alatum Pursh. Frequent in wet ground; 773, 836.
Lythrum salicaria L. Locally abundant in wet ground; 440.
**Rotala ramosior* (L.) Koehne. Local in wet ground; 814.

Cactaceae Lindl.

Opuntia rafinesquii Engelm. Local on high, exposed, limestone ledge; 2800.

Cucurbitaceae B. Juss.

Echinocystis lobata (Michx.) T. & G. Local along the edge of woods; 516.

Onagraceae Dumort.

Circaea latifolia Mill. Frequent in woods; 67, 707.
**Epilobium coloratum* Muhl. Locally abundant in wet ground; 461, 499, 882.
**Gaura biennis* L. Local along the edge of woods; 509.
Oenothera biennis L. Frequent in open woods and open ground; 150, 212, 781.

Aristolochiaceae Blume

Asarum acuminatum (Ashe) Bickn. Common in rich woods; 634.

Santalaceae R. Br.

Comandra umbellata (L.) Nutt. Local in dry open woods and hill prairies; 590, 823, 975.

Cornaceae Link

Cornus alternifolia L.f. Common in rich woods; 62.
Cornus drummondii C. A. Mey. Frequent in open woods; 95, 1064.
Cornus racemosa Lam. Frequent along the edge of woods; 118, 449.

Araliaceae Vent.

Aralia nudicaulis L. G. D. Fuller 17154 (ISM).
Aralia racemosa L. Frequent in rich woods; 172, 222.

Umbelliferae Scop.

Cicuta maculata L. Local in wet ground; 171, 969.
Cryptotaenia canadensis (L.) DC. Frequent in woods; 671.
Daucus carota L. Frequent in open ground; 117.
**Eryngium yuccifolium* Michx. Local in prairies; 244.
Osmorhiza claytonii (Michx.) Clarke. Frequent in rich woods; 188.
Osmorhiza longistylis (Torr.) DC. Local in rich woods; 2685.
Sanicula canadensis L. R. A. Evers 61507 (ILLS).
**Sanicula gregaria* Bickn. Frequent in woods; 711.
Sium suave Walt. Local in wet ground; 2766.
Zizia aurea (L.) Koch. Local in open woods; 795.

Ericaceae DC.

Monotropa uniflora L. R. A. Evers 58755 (ILLS).
Pyrola elliptica Nutt. R. A. Evers 10677 (ILLS).

Primulaceae Vent.

Dodecatheon amethystinum Fassett. Locally abundant on rocky, wooded slopes and bluff tops; 628.
Lysimachia ciliata L. Frequent in moist ground; 121.

Oleaceae Lindl.

Fraxinus americana L. Local in woods; 46-A.
Fraxinus lanceolata Borkh. Local in woods; 46, 502.
**Fraxinus pennsylvanica* Marsh. Local in woods; 941.
**Ligustrum vulgare* L. Persistent from cultivation near the site of old dwellings; 2728.
**Syringa vulgaris* L. Persistent from cultivation near the sites of old dwellings; 2507.

Apocynaceae Lindl.

**Apocynum androsaemifolium* L. Local in open woods; 2683.
**Apocynum cannabinum* L. Local in open woods; 972.
**Apocynum medium* Greene. Local in open woods; 47, 712.

Asclepiadaceae Lindl.

**Asclepias exaltata* (L.) Muhl. Local in rich woods; 2755.
Asclepias incarnata L. Frequent in wet ground; 932.
**Asclepias purpurascens* L. Local in open woods; 676.
Asclepias syriaca L. Frequent in open ground; 942.
**Asclepias tuberosa* L. Frequent in open ground; 802.
Asclepias verticillata L. Frequent in prairies and open ground; 132, 443.

Polemoniaceae Juss.

Phlox divaricata L. Common in rich woods; 797, 798.
**Phlox paniculata* L. Local in open ground; 2725.
Phlox pilosa L. Local in open woods; 826.

Convolvulaceae Vent.

**Convolvulus americanus* (Sims) Greene. Local in waste ground; 948.
**Convolvulus arvensis* L. Local in waste ground; 2667.
**Cuscuta compacta* Juss. Local in moist woods; 813, 1072.

Hydrophyllaceae Lindl.

Ellisia nyctelea L. Local in open ground; 2508.
Hydrophyllum virginianum L. Common in rich woods; 832.

Solanaceae Pers.

**Physalis heterophylla* Nees. Local in open grounds; 468.
Physalis virginiana Mill. Local in open ground; 2663.
Solanum carolinense L. Local in open ground; 829.
Solanum nigrum L. Local in waste ground and open woods; 196, 1060.

Scrophulariaceae Lindl.

Aureolaria grandiflora (Benth.) Pennell. Local in open woods; 240, 445.
Castilleja coccinea (L.) Spreng. R. A. Evers 12706 (ILLS).
**Chaenorrhinum minus* (L.) Lange. Local in waste ground; 2664.
**Gerardia tenuifolia* Vahl. Local in wet ground; 619, 812.
**Gratiola neglecta* Torr. Local in wet ground; 991.
**Lindernia dubia* (L.) Pennell. Local in wet ground; 1075.
Penstemon pallidus Small. Frequent in hill prairies; 677, 845.
Scrophularia marilandica L. Local in woods; 178.
Synthyris bullii (Eaton) Heller. Local on shaded bluff tops; 653.
Verbascum thapsus L. Local in waste ground; 50.
**Veronica peregrina* L. Frequent in waste ground; 962.
Veronicastrum virginicum (L.) Farw. Local in open ground; 140, 959.

Bignoniaceae Pers.

**Campsis radicans* (L.) Seem. Local near the site of old dwelling; 2724.

Plantaginaceae Lindl.

Plantago aristata Michx. Local in waste ground; 944.
**Plantago lanceolata* L. Frequent in open ground; 105, 673.
Plantago rugelii Dec. Common in open ground; 106.

Boraginaceae Lindl.

Cynoglossum officinale L. R. A. Evers 10633 (ILLS).
**Hackelia americana* (A. Gray) Fern. Local in open woods; 2753.
Hackelia virginiana (L.) I. M. Johnst. Frequent in open woods; 192.
Lithosperum canescens (Michx.) Lehm. Frequent in hill prairies and local in open woods; 592, 660, 849.
**Mertensia virginica* (L.) Pers. Frequent in rich woods; 662.

Verbenaceae J. St. Hil.

Phyla lanceolata (Michx.) Greene. Frequent in wet ground; 837.
Verbena bracteata Lag. & Rodr. Frequent in waste ground; 472.
Verbena hastata L. Local in open ground; 148, 208.
Verbena stricta Vent. Common in waste ground and prairies; 49, 130.
Verbena urticifolia L. Local in open ground; 136.

Phrymaceae Schauer

Phryma leptostachya L. Frequent in woods; 127.

Labiatae Juss.

**Agastache nepetoides* (L.) Ktze. Local in moist open woods; 2770.
Hedeoma hispida Pursh. Local in dry open ground; 2506.
**Isanthus brachiatus* (L.) BSP. Local in open ground; 990.
**Leonurus cardiaca* L. Local in open ground; 44.
Lycopus americanus Muhl. Frequent in wet ground; 174, 497.
**Lycopus rubellus* Moench. Local in wet ground; 205.
Mentha canadensis L. Frequent in wet ground; 951.
Monarda fistulosa L. Common in prairies and open ground; 79.
Nepeta cataria L. Local in open ground; 42.
**Physostegia speciosa* Sweet. Local in wet ground; 883.
Prunella vulgaris L. Frequent in open ground; 126.
Pycnanthemum pilosum Nutt. R. A. Evers 58767 (ILLS).
Pycnanthemum virginianum (L.) Dur. & Jacks. Frequent in prairies and open ground; 131, 953-A.
Scutellaria lateriflora L. Local in wet ground; 191.
Scutellaria leonardii Epling. Frequent on exposed bluff tops; 848.

Scutellaria ovata Hill. Frequent in woods; 74, 687.
Teucrium canadense L. Frequent in open ground; 120.

Rubiaceae B. Juss.

Cephalanthus occidentalis L. Local in wet ground; 884.
Galium circaezans Michx. R. A. Evers 13841 (ILLS).
Galium concinnum T. & G. Frequent in open woods; 183, 678.
Galium obtusum Bigel. Frequent in moist woods; 949.
Galium triflorum Michx. Frequent in moist woods; 71, 185.

Capifoliaceae Vent.

Lonicera japonica Thunb. R. A. Evers 24474 (ILLS).
Lonicera prolifera (Kirchn.) Redh. R. M. Myers *s.n.* (WIU).
**Sambucus canadensis* L. Local along the edge of woods; 63.
Symphoricarpos occidentalis Hook. Local in open woods; 508.
Triosteum aurantiacum Bickn. Local in open woods; 246.
Viburnum lentago L. R. A. Evers 10645 (ILLS).
Viburnum rafinesquianum Schultes. Local in woods; 69.

Campanulaceae Juss.

Campanula americana L. Frequent in woods; 218.
Campanula intercedens Witasek. Frequent on rocky outcrops; 91, 667.
**Specularia perfoliata* (L.) A. DC. Local in waste ground; 876.

Lobeliaceae Dum.

Lobelia cardinalis L. Local in wet ground; 774.
Lobelia inflata L. Frequent in open ground; 442.
Lobelia siphilitica L. Frequent in moist ground; 190.
**Lobelia spicata* Lam. Frequent in prairies; 957.

Compositae P. F. Gmel.

**Achillea lanulosa* Nutt. Local in waste ground; 2092.
Achillea millefolium L. Frequent in open ground; 147.
Ambrosia artemisiifolia L. Frequent in waste ground; 444.
Ambrosia trifida L. Frequent in waste ground; 490.
Antennaria neglecta Greene. R. A. Evers 42018 (ILLS).
Antennaria plantaginifolia (L.) Hook. Frequent in open ground; 635, 986.
Arctium minus (Hill) Bernh. Local in waste ground; 180.
Artemisia caudata Michx. Frequent on exposed limestone cliffs; 602.
Aster azureus Lindl. R. A. Evers 58752 (ILLS).
Aster ericoides L. R. A. Evers 58731 (ILLS).
Aster laevis L. Local in woods; 859.
Aster lateriflorus (L.) Britt. Frequent in woods; 857, 858, 860.
Aster novae-angliae L. Local along the edge of woods; 604.
**Aster parviceps* (Burgess) Mack. & Bush. Local in open woods; 608, 864, 1055.
Aster pilosus Willd. Frequent along the edge of woods; 612, 815.
Aster sagittifolius Wedem. Local in open woods; 2729.
Aster shortii Lindl. Local in open woods; 609, 1068.
**Aster simplex* Willd. Local in moist ground; 994.
Bidens comosa (A. Gray) Weig. Local in wet ground; 498, 873.
**Bidens frondosa* L. Local in wet ground; 821, 853, 1066.
Bidens vulgata Greene. Local in wet ground; 2721.
**Chrysanthemum leucanthemum* L. Local in open ground; 182.
Cirsium altissimum (L.) Spreng. Local along the edge of woods; 503.
Cirsium discolor (Muhl.) Spreng. Local in open ground; 603.
Cirsium vulgare (Savi) Tenore. Local in open ground; 505.
Coreopsis palmata Nutt. Local in hill prairies and open woods; 2681.
**Erechtites hieracifolia* (L.) Raf. Local along the edge of woods; 1073.
Erigeron canadensis L. Common in open ground; 453.
Erigeron philadelphicus L. Local in open woods; 824.
Erigeron pulchellus Michx. Local in open woods; 881.
Erigeron strigosus Muhl. Frequent in open ground: 78.
Eupatorium altissimum L. Frequent along the edge of woods; 482, 777.
**Eupatorium perfoliatum* L. Local in wet ground; 207.
Eupatorium purpureum L. Local along the edge of woods; 157.
Eupatorium rugosum Houtt. Common in woods; 219.
Eupatorium serotinum Michx. Local in wet ground; 511, 954.

**Galinsoga parviflora* Cav. Local in waste ground; 204.
Gnaphalium obtusifolium L. Local in prairies; 450.
**Helenium autumnale* L. Local in wet ground; 874.
**Helianthus decapetalus* L. Local in woods; 249.
Helianthus grosseserratus Martens. Local along the edge of woods; 2658.
**Helianthus hirsutus* Raf. Local along the edge of woods; 446.
Helianthus strumosus L. Local in open woods; 613.
**Helianthus tomentosus* Michx. Local along the edge of woods; 241.
**Heliopsis helianthoides* (L.) Sweet. Local in prairies; 72.
**Hieracium canadense* Michx. Local along the edge of woods; 852.
Krigia biflora (Walt.) Blake. R. A. Evers 37770 (ILLS).
Kuhnia eupatorioides L. Local in prairies; 783, 877.
Lactuca canadensis L. Frequent in prairies; 156, 816, 854.
Lactuca floridana (L.) Gaertn. Frequent in woods; 517.
Liatris aspera Michx. Frequent in prairies; 452.
Liatris cylindracea Michx. R. A. Evers 28206 (ILLS).
Matricaria matricarioides (Less.) Porter. Local in waste ground; 872.
Parthenium integrifolium L. Local in prairies; 782.
Polymnia canadensis L. Local in woods; 73, 672.
**Prenanthes alba* L. Frequent in woods; 779.
Ratibida pinnata (Vent.) Barnh. Common in prairies; 77.
Rudbeckia hirta L. Frequent in prairies and open ground; 76, 104.
Senecio pauperculus Michx. R. A. Evers 29909 (ILLS).
Senecio plattensis Nutt. Frequent in open ground; 878.
Silphium perfoliatum L. Local in wet ground; 142.
Solidago altissima L. Frequent along the edge of woods; 493.
**Solidago gigantea* Ait. Frequent in wet ground; 820, 862.
Solidago glaberrima Martens. Common in prairies; 143, 226, 447.
**Solidago hispida* Muhl. Frequent on exposed limestone cliffs; 199.
Solidago latifolia L. Frequent in woods; 495, 1067.
Solidago nemoralis Ait. Frequent in prairies; 605, 606, 869.
Solidago rigida L. Frequent in prairies; 616, 785.
Solidago sciaphila Steele. L. H. Shinners (ILL).
Solidago speciosa Nutt. Frequent in prairies; 615, 868.
Solidago ulmifolia Muhl. Frequent in woods; 494, 803, 953.
**Sonchus oleraceus* L. Frequent in waste ground; 202.
Taraxacum officinale Wiggers. Common in open ground; 206.
Tragopogon dubius Scop. Frequent in open ground; 82.
Tragopogon pratensis L. Frequent in open ground; 2726.
**Vernonia fasciculata* Michx. Local in wet ground and along the edge of woods; 455.
**Xanthium commune* Britt. Local in wet ground; 2723.

Alismaceae DC.

Alisma subcordatum Raf. Local in wet ground; 2793.
Sagittaria latifolia Willd. Frequent in shallow water; 459.

Naiadaceae Lindl.

**Naias flexilis* (Willd.) R. & S. Frequent in shallow water; 923.

Potamogetonaceae Engler

**Potamogeton americanus* C. & S. Frequent in shallow water; 209, 218.
**Potamogeton crispus* L. Frequent in shallow water; 919.
**Potamogeton foliosus* Raf. Common in shallow water; 914.
**Potamogeton pectinatus* L. Frequent in shallow water; 518, 915.
**Potamogeton pusillus* L. Frequent in shallow water; 958.
**Zannichellia palustris* L. Frequent in shallow water; 922.

Liliaceae Adans.

Allium tricoccum Ait. Frequent in rich woods; 186.
Asparagus officinalis L. Local along the edge of woods; 221.
**Convallaria majalis* L. Persisting from cultivation near the site of old dwelling; 2500.
**Erythronium albidum* Nutt. Frequent in rich woods; 789.
**Erythronium americanum* Ker. Local in rich woods; 790.
**Hemerocallis fulva* L. Locally abundant along the edge of woods; 2674.
Hosta lancifolia (Thunb.) Engler. R. H. Mohlenbrock 7214 (SIU).

Polygonatum commutatum (Schultes) Dietr. Local along the edge of woods; 231.
Smilacina racemosa (L.) Desf. Frequent in open woods; 232.
Smilacina stellata (L.) Desf. Frequent in open woods; 591.
Smilax hispida Muhl. Frequent in open woods; 201.
Smilax lasioneura Hook. R. A. Evers 29916 (ILLS).
**Trillium grandiflorum* (Michx.) Salisb. Frequent in rich woods; 649, 654, 663.
**Trillium recurvatum* Beck. Common in woods; 630.
Uvularia grandiflora Sm. Common in woods; 688.

Juncaceae Vent.

Juncus bufonius L. Locally abundant in wet ground; 2682.
**Juncus dudleyi* Wieg. Local in wet ground; 2099.
Juncus tenuis Willd. Common in open woods; 457.
**Juncus torreyi* Coville. Local in wet ground; 441.

Commelinaceae Reichenb.

**Commelina communis* L. Local along the edge of woods; 70.
Tradescantia ohiensis Raf. Local in open ground; 939.

Pontederiaceae Dumort.

**Heteranthera dubia* (Jacq.) MacM. Locally abundant in shallow water; 916.

Amaryllidaceae Lindl.

**Hypoxis hirsuta* (L.) Coville. Local in open woods and hill prairies; 825.

Iridaceae Lindl.

Iris shrevei Small. Local in wet ground; 2672.
Sisyrinchium campestre Bickn. Local in open woods and hill prairies; 656.

Dioscoreaceae Lindl.

**Dioscorea villosa* L. Local in open woods; 2692.

Orchidaceae Lindl.

Crypripedium parviflorum Salisb. Local in rich woods; 822.
Goodyera pubescens (Willd.) R. Br. Local in woods; 227.
Liparis lilifolia (L.) Rich. R. A. Evers 58759 (ILLS).
**Spiranthes gracilis* (Bigel.) Beck. Frequent in prairies; 772.

Araceae Necker

Acorus calamus L. Locally abundant in wet ground; 2090.
Arisaema triphyllum (L.) Schott. Frequent in rich woods; 636.

Lemnaceae Dumort.

**Lemna minor* L. Common in shallow water; 1080.
**Lemna trisulca* L. Locally abundant in shallow water; 921.
**Spirodela polyrhiza* (L.) Schleid. Common in shallow water; 800.
**Wolffia columbiana* Karst. Frequent in shallow water; 801.

Typhaceae J. St. Hil.

Typha latifolia L. Frequent in shallow water; 460, 850.

Cyperaceae J. St. Hil.

Carex bicknellii Britt. Local in prairies; 146.
Carex blanda Dewey. Frequent in open woods; 1008.
Carex cephalophora Muhl. Frequent in open woods; 842.
**Carex convoluta* Mack. Frequent in woods; 985.
**Carex cristatella* Britt. Frequent in wet ground; 976, 979, 980.
Carex eburnea Boott. Local in dry open woods; 456.
**Carex gracillima* Schw. Local in woods; 633.
Carex hystricina Muhl. Frequent in wet ground; 237.
Carex laeviconica Dewey. Local in wet ground; 2802.
**Carex lupuliformis* Sartw. Frequent in wet ground; 837, 960, 967.
Carex normalis Mack. R. A. Evers 37781 (ILLS).
Carex pennsylvanica Lam. Common in open woods; 625, 793.
.*Carex rosea* Schk. R. A. Evers 37759 (ILLS).
**Carex scoparia* Schk. Local in wet ground; 2801.
Carex sparganioides Muhl. R. A. Evers 10645 (ILLS).
Carex sprengelii Dewey. Frequent in wet ground; 938.
**Carex tribuloides* Wahl. Frequent in wet ground; 1043.
**Carex vescaria* L. Frequent in wet ground; 835.
Carex vulpinoidea Michx. Frequent in wet ground; 834, 934.
**Cyperus acuminatus* Torr. & Hook. Local in wet ground; 983.
**Cyperus strigosus* L. Local in wet ground; 976, 1037.

**Eleocharis acicularis* (L.) R. & S. Local in wet ground; 2839.
**Eleocharis ovata* (Roth.) R. & S. Local in wet ground; 1077.
**Eleocharis palustris* (L.) R. & S. Local in wet ground; 2841.
Scirpus atrovirens Willd. Frequent in wet ground; 170, 851.

Gramineae Juss.

Agropyron repens (L.) Beauv. Frequent in open ground; 2696.
**Agropyron smithii* Rydb. Local in waste ground; 977.
Agrostis alba L. Common in open ground; 52.
**Agrostis hyemalis* (Walt.) BSP. Frequent in open ground; 830.
**Agrostis perennans* (Walt.) Tuckerm. R. A. Evers 58750 (ILLS).
Andropogon furcatus Muhl. Common in prairies; 464.
Andropogon scoparius Michx. Common in hill prairies; 601.
Aristida basiramea Englm. R. A. Evers 28186 (ILLS).
**Aristida intermedia* Scribn. & Ball. R. A. Evers 28211 (ILLS).
Aristida oligantha Michx. Frequent in open ground; 778.
Bouteloua curtipendula (Michx.) Torr. Common in hill prairies; 133.
Bouteloua hirsuta Lag. Local in hill prairies; 454.
**Brachyelytrum erectum* (Screb.) Beauv. Local in woods; 2787.
Bromus inermis Leyss. Frequent along the edge of woods; 204, 681.
**Bromus latiglumis* (Shear) Hitchc. Local along the edge of woods; 510.
Bromus tectorum L. Local in waste ground; 2509.
**Calamagrostis canadensis* (Michx.) Beauv. Frequent in wet ground; 1078.
Cenchrus pauciflorus Benth. Local in waste ground; 481.
Cinna arundinacea L. Local in wet ground; 2796.
**Dactylis glomerata* L. Frequent in open ground; 674, 796.
**Digitaria ischaemum* (Schreb.) Muhl. Frequent in open ground; 488.
Digitaria sanguinalis (L.) Scop. Frequent in open ground; 2718.
Echinochloa crusgalli (L.) Beauv. Frequent in wet ground; 175, 462.
**Echinochloa walteri* (Pursh) Heller. Local in wet ground; 930, 971.
**Eleusine indica* (L.) Gaertn. R. A. Evers 61498 (ILLS).
Elymus canadensis L. Frequent along the edge of woods; 927.
**Elymus villosus* Muhl. Frequent along the edge of woods; 85, 666.
**Elymus virginicus* L. Frequent along the edge of woods; 600.
**Eragrostis capillaris* (L.) Nees. Local in open woods; 217.
Eragrostis cilianensis (All.) Lut. Local in open ground; 485.
Eragrostis pectinacea (Michx.) Nees. Local in open ground; 480.
Eragrostis spectabilis (Pursh) Steud. R. A. Evers 28192 (ILLS).
**Glyceria striata* (Lam.) Hitchc. Frequent in wet ground; 2675.
**Hystrix patula* Moench. Frequent in woods; 51.
Koeleria cristata (L.) Pers. Local in dry soil; 847.
**Leersia lenticularis* Michx. Locally abundant in wet ground; 2765.
Muhlenbergia frondosa (Poir.) Fern. Frequent in open woods; 614.
**Muhlenbergia racemosa* (Michx.) BSP. Frequent in wet ground; 611, 893.
**Muhlenbergia schreberi* J. F. Gmel. R. A. Evers 58736 (ILLS).
**Muhlenbergia tenuiflora* (Willd.) BSP. Local in woods; 506, 1071.
**Panicum capillare* L. Frequent in open ground; 479.
Panicum huachucae Ashe. Frequent in open woods and prairies; 686, 843.
Panicum latifolium L. Local in moist woods; 844.
Panicum scribnerianum Nash. R. A. Evers 28177 (ILLS).
Panicum virgatum L. Common in prairies; 119, 145.
**Paspalum pubescens* Muhl. Local in open ground; 819.
**Phalaris arundinacea* L. Frequent in wet ground; 926, 964.
Phleum pratense L. Common in open ground; 112.
Poa compressa L. Common in open ground; 993, 2785.
Poa pratensis L. Common in open ground; 2084.
Setaria lutescens (Weigel) F. T. Hubb. Frequent in open ground; 1063.
Setaria viridis (L.) Beauv. Frequent in open ground; 484.
Sorghastrum nutans (L.) Nash. Common in prairies; 463.
Spartina pectinata Link. Frequent in wet ground; 167.
**Sphenopholis intermedia* Rydb. R. A. Evers 24449 (ILLS).
Sporobolus asper (Michx.) Kunth. R. A. Evers 28169 (ILLS).
Sporobolus cryptandrus (Torr.) A. Gray. Local in dry soil; 952.

**Tridens flavus* (L.) Hitchc. Local in open ground; 507.
**Triticum aestivum* L. Local in waste ground; 2660.
**Zizania aquatica* L. Local in shallow water; 210.

Acknowledgments

This paper is based in part upon a thesis submitted by the author to the graduate faculty of the Department of Biological Sciences at Western Illinois University in partial fulfillment of the requirements of the master of science degree.

The author expresses his appreciation to Dr. R. M. Myers, Western Illinois University, for assistance given during this investigation, Mr. F. J. Stiles, Park Ranger of the Mississippi Palisades State Park, for his cooperation and to the curators of the herbaria whose facilities were used during this investigation.

The author wishes to acknowledge Dr. R. H. Mohlenbrock, Southern Illinois University, for his critical reading of the manuscript.

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Manuscript received December 3, 1966.

THE ILLINOIS SPECIES OF HALORAGACEAE AND HIPPURIDACEAE

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ABSTRACT.—Five species of *Myriophyllum*, one of *Proserpinaca*, and one of *Hippuris* are recorded. *Myriophyllum hippuroides* is reported from Illinois for the first time. Keys, descriptions, discussions, distribution maps, and line illustrations are provided for each species.

All three genera considered in this study were created by Linnaeus in 1753. There has never been difficulty on the part of botanists in separating the genera, and the names *Hippuris*, *Myriophyllum*, and *Proserpinaca* have been used by almost all workers. An exception to this was the employment of the name *Burshia* by Rafinesque (1808) for a species of *Myriophyllum*. Another misinterpretation was Walter's placing of a species of *Myriophyllum* within *Potamogeton*.

Although little confusion has existed on the generic level, varying opinions have been raised on the placement of these genera within families. Generally, two schools of thought have prevailed. One has been to consider all three genera to belong to the single family Haloragaceae (sometimes spelled Halorrhagaceae, Haloragidaceae, or Halorrhagidaceae). This has been adhered to by Petersen (1889), Hallier (1905), Hutchinson (1926), Fassett (1940), Jones (1945, 1950, 1964), and Jones and Fuller (1955).

The other trend has been to keep *Myriophyllum* and *Proserpinaca* in the Haloragaceae, and to segregate *Hippuris* into its own family, the Hippuridaceae, because of the linear, entire leaves in whorls of six or more, the sympodial branching of the stem, the bisexual flowers without a perianth, and the single stamen, ovule, and style of *Hippuris*. This has been followed by Schindler (1904, 1905), Bessey (1915), Rendle (1925), Wettstein (1935), Fernald (1950), and Gleason (1952). It is this latter view that is maintained in this study.

Mead was apparently the first botanist to record any of these taxa from Illinois when he listed *Myriophyllum heterophyllum*, *M. verticillatum*, and *Proserpinaca palustris* in 1846. By 1876, Patterson was able to record four species of *Myriophyllum* and one each of *Hippuris* and *Proserpinaca* from Illinois. No additions were made to these genera in Illinois for 89 years, or until a fifth species of *Myriophyllum* was discovered during this study. Several authors in the past have attributed still another species of *Myriophyllum (M. humile)* to Illinois, but this was not verified during our study.

The authors wish to thank the curators of the following herbaria for providing study material.

F—Chicago Museum of Natural History
ILL—University of Illinois
ILLS—Illinois Natural History Survey
ISM—Illinois State Museum
MO—Missouri Botanical Garden
SIU—Southern Illinois University

The senior author prepared the illustrations.

Morphology of the Genera

The species of *Myriophyllum* and *Hippuris* are usually submerged aquatics, rarely becoming terrestrial. *Proserpinaca* is amphibious, occurring both submerged in water and emergent onto land. The stems are simple or sparsely branched and glabrous. Submerged and usually emersed leaves occur. The submerged leaves, which range from 0.8-7.0 cm long, are shallowly incised or capillary-pinnate with 5-13 pairs of divisions. The emersed leaves in *Myriophyllum,* when developed, may resemble the floral bracts or the submerged leaves. In *Proserpinaca,* the emersed leave are merely serrate. In *Hippuris,* the emersed leaves are entire and are borne in whorls of six to twelve.

The flowers are perfect in *Proserpinaca,* perfect or unisexual in the other genera. They are borne singly or in clusters of 2-5 in the axils of floral bracts. The bracts are whorled, linear to spatulate to obovate, entire, serrate, or pinnatisect. There are four petals in *Myriophyllum,* ranging from 1.5-3.0 mm long, three minute petals in *Proserpinaca,* and none in *Hippuris.*

The fruit, which provides some of the best diagnostic characters, is ovoid and 4-sulcate in *Myriophyllum* and 3-angled in *Proserpinaca.* In *Hippuris,* the fruit is 1-seeded, indehiscent, and nut-like.

Ecological Considerations

The Haloragaceae and Hippuridaceae are aquatic families in Illinois with the individual species living either submerged, partially submerged in water, or rooted in the muddy banks of pools, streams, and lakes. The Illinois species of *Myriophyllum* occur in quiet waters of ponds and streams, sending fertile spikes containing bracts and flowers above the water level. *Proserpinaca* is an amphibious genus which may or may not develop the typical submerged dissected leaf of the family. *Hippuris,* when completely submerged, is sterile with scale-like leaves; the fertile forms grow only in shallow water.

Geographical Considerations

The genus *Myriophyllum* is composed of about 40 species, 5 of which have been found in Illinois. In general these Illinois species range from Nova Scotia to Alaska, are greatly scattered throughout the United States and into Mexico, and are distributed widely in Europe.

The discovery of a specimen of *M. hippuroides* at F establishes a state record for this species. Previously the range for this plant extended from New York to Wisconsin and from Washington to California.

In Illinois, *M. pinnatum* is reported from many of the counties in the southern two-thirds of the state. *Myriophyllum verticillatum* and *M. heterophyllum* show a scattered distribution throughout the entire state but cannot be considered abundant. The remaining species, *M. exalbescens,* is known from four northern counties and two in the central part of the state.

The irregular distribution of these five species leads the authors to believe that further collecting will be necessary to give a more complete and correct picture of the distribution of *Myriophyllum* in Illinois.

Fernald (1950) states that the genus *Proserpinaca* is composed of three species and two varieties. Only *P. palustris* is found in Illinois. This species ranges from Nova Scotia and Quebec, across the northern United States, and south to Florida, Louisiana, and down into Mexico, Central America, and the West Indies.

In Illinois, *Proserpinaca palustris* shows a limited distribution throughout the state but is found both in the northern- and southern-most counties. Again, more concentrated collecting may show this species to be a more common Illinois plant.

The genus *Hippuris* has two species, one of which is known from Illinois. The Illinois species, *H. vulgaris,* shows a wide distribution across southern Canada to Alaska, southeast to New Mexico and east across Nebraska and Illinois to New York. It is also found in Europe.

In Illinois, only three northern counties—Lake, McHenry, and Kane—have records of this species.

Systematic Treatment

Key to the Families
Haloragaceae and Hippuridaceae

1. Stem branching occasionally; leaves usually of two kinds: the submerged leaves deeply pinnatisect, the emersed leaves (as well as the bracts) serrate; fruit 3- to 4-locular..... .....Family Haloragaceae
1. Stem unbranched; leaves of one kind, whorled, simple, entire; fruit 1-locular.....Family Hippuridaceae

Haloragaceae—Water Milfoil Family

Key to the Illinois
Genera of Haloragaceae

1. Leaves whorled or scattered, crowded; flower 4-merous; fruit 4-angled .....1. *Myriophyllum*
1. Leaves alternate, rather remote; flower 3-merous; fruit 3-angled ....2. *Proserpinaca*

1. *Myriophyllum* L.—Water Milfoil

Myriophyllum L. Sp. Pl. 992. 1753.
Burshia Raf. Med. Rep. II. 5:357. 1808.

Aquatic or rarely terrestrial; stem usually branched; submerged leaves whorled or alternate, capillary-pinnate with 5-13 divisions; emersed leaves, if developed, serrate or pinnatifid; bracts whorled, entire, serrate, or pinnatifid; flowers axillary, perfect or unisexual, 4-merous; fruit 4-sulcate, anteriorly beaked.

Key to the Illinois
Species of *Myriophyllum*

1. Leaves verticillate and scattered; bracts entire to deeply toothed and exceeding the flower; stamens 4; fruit with 4 dorsal tuberculate or undulate ridges.
   2. Bracts entire to pectinate; fruit 4-angled, with each section flattened, slightly papillose with a smooth dorsal ridge with undulate margins.....1. *M. hippuroides*
   2. Bracts deeply toothed; fruit 4-angled, with each section rounded, smooth, with a tuberculate dorsal ridge.....2. *M. pinnatum*
1. Leaves all verticillate; bracts entire to pinnatifid, sometimes exceeding the flower; stamens 4 or 8; fruit without dorsal ridges or, if present, smooth.
   3. Bracts deeply pinnatifid; stamens 8; fruit 4-angled, sections rouuded, smooth....3. *M. verticillatum*
   3. Bracts entire to serrate; stamens 4; fruit 4-angled, sections with dorsal ridges smooth, or slightly tuberculate without ridges.
      4. Bracts entire to serrate, much exceeding flower; fruit with smooth dorsal ridges..... .....4. *M. heterophyllum*
      4. Bracts entire to denticulate, not exceeding flower; fruit somewhat tuberculate, without dorsal ridges..... .....5. *M. exalbescens*

1. *Myriophyllum hippuroides* Nutt. ex Torr. & Gray, Fl. N. Am. 1:530. 1840. (Fig. 1).

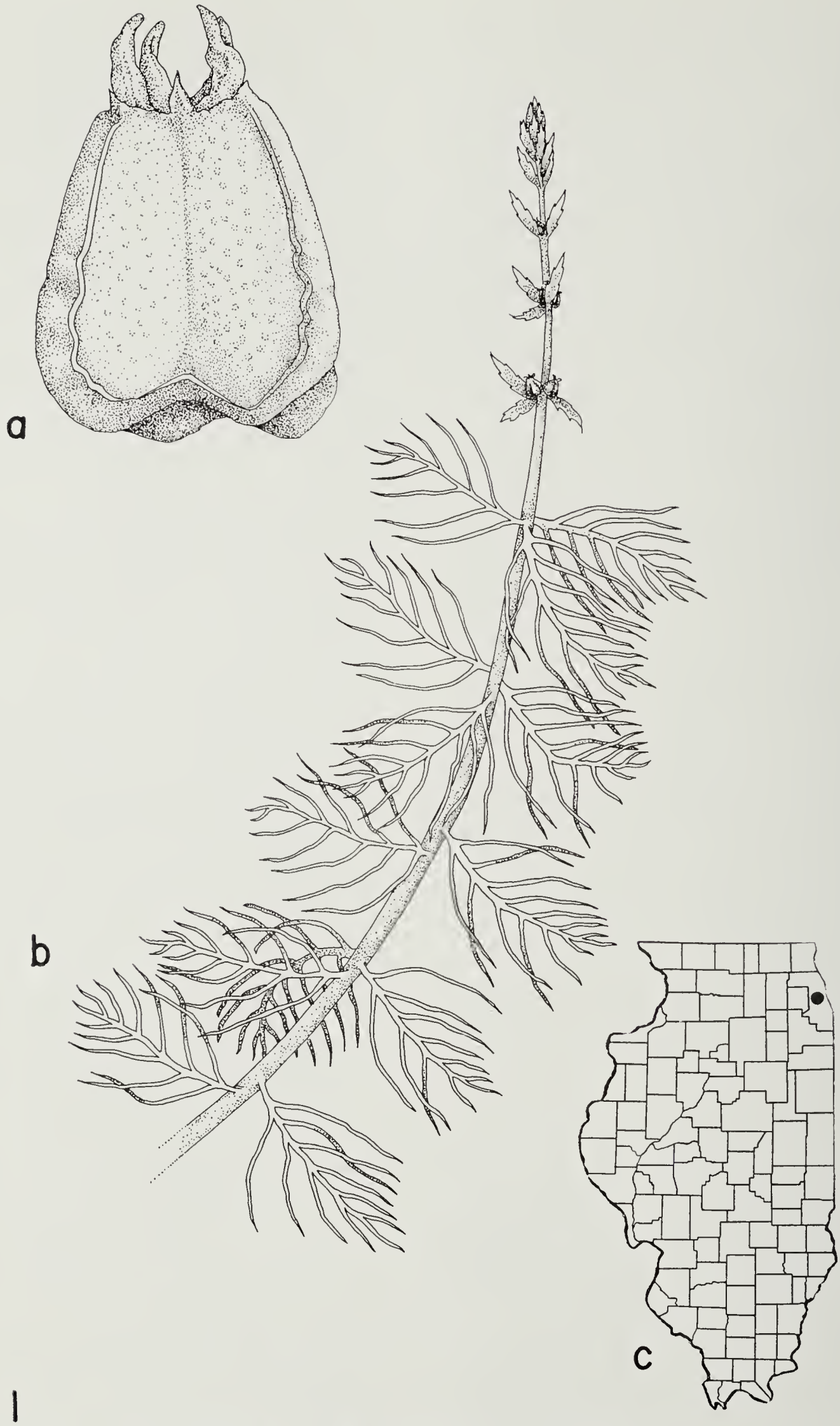

FIGURE 1.—*Myriophyllum hippuroides* Nutt. a. Fruit, X 00. b. Plant, X 0. c. Illinois distribution.

Myriophyllum verticillatum var. cheneyi Fassett, in Rhodora 41:524. 1939.

Submerged; stem sparsely branched; submerged leaves verticillate or subverticillate, to 4.5 cm long, capillary-pinnate with 5-10 pairs of divisions; emersed leaves deeply toothed; floral bracts whorled, linear to lanceolate, 0.5-2.0 cm long, entire or shallowly toothed; flowers axillary, perfect or unisexual; petals 1.5-3.0 mm long; stamens 4; fruit ovoid, 1.6-2.0 mm long, deeply 4-sulcate, each section somewhat papillose with a dorsal ridge with slightly undulate margins and an anterior beak.

Habitat.—Shallow water.

Range.—New York to Wisconsin; Illinois; Washington to California.

Myriophyllum hippuroides closely resembles *M. pinnatum* but may be distinguished by its bracts and fruit. The bracts of *M. hippuroides* are entire or slightly toothed and the 4-angled fruit has smooth to undulate ridges rather than conspicuously tuberculate ridges.

Myriophyllum hippuroides was described by Nuttall in 1840, but nearly one hundred years later, Fassett considered it a variety of *M. verticillatum*. The submerged leaves of *M. hippuroides* are whorled and scattered, in *M. verticillatum* only whorled. Floral bracts of *M. hippuroides* are entire or with 2-4 pairs of shallow teeth: floral bracts of *M. verticillatum* are deeply toothed. The flower of *M. hippuroides* has 4 stamens; that of *M. verticillatum* has 8 stamens. The fruits differ in several respects. *Myriophyllum hippuroides* has an ovoid, strongly 4-sulcate fruit with each section flattened and covered with minute papillae. On the dorsal edge of each segment is a smooth ridge with occasional undulations along the margins. The fruit of *M. verticillatum* is ovoid, plump, and not deeply divided. The individual sections are rounded, smooth, and without a dorsal ridge. It appears justifiable to recognize *M. hippuroides* as a valid species.

This is the first report of this species from Illinois.

Specimen Examined.—Cook: *A. Hall 174* (F).

2. *Myriophyllum pinnatum* (Walt.) BSP. Prel. Cat. N.Y. 16. 1888. (Fig. 2).

Potamogeton pinnatum Walt. Fl. Car. 90. 1788.

Myriophyllum scabratum Michx. Fl. Bor. Am. 2:190. 1803.

Either submerged or terrestrial; stem sparsely branched; submerged leaves verticillate, subverticillate, or scattered, 1-3 cm long, capillary-pinnate with about 5 pairs of divisions; emersed leaves developing occasionally and resembling bracts; floral bracts whorled, linear, 0.5-2.0 cm long, conspicuously toothed with 3-5 pairs of teeth; flowers axillary, perfect or unisexual; petals 1.5-2.0 mm long, rounded above; stamens 4; fruit ovoid, 1.3-2.0 mm long, deeply 4-sulcate, each section with a dorsal, tuberculate, slightly concave ridge and anterior beak.

Habitat.—Rooted in muddy shores or in shallow waters of ponds and lakes.

Range.—Massachusetts to North Dakota, south to Texas and Florida; Mexico.

Myriophyllum pinnatum may be distinguished in several respects. The submerged pinnatified leaves are both whorled and scattered along the stem. The floral bracts, which are borne on an emersed spike, are linear, irregularly toothed, and much exceed the flower. Each lobe of the 4-sectioned fruit has a conspicuous dorsal tuberculate ridge terminated at the apex by a beak.

Specimens Examined.—Cass: *Rexroat 3772* (ISM). Hancock: south of Warsaw, *Collector unknown*. Henderson: near Oquawka, *Patterson s.n.* (ILL). Mason: W of Saidora, *Rexroat 4763* (ISM). Pike: W of Meredosia, *Rexroat 6281* (ISM). Randolph: W of Sparta, *Swayne & Bailey 1007* (SIU). St. Clair: S of French Village, *Winterringer 10750* (ISM). Schuyler: without locality, *Rexroat 1687* (ISM). Vermilion: Oakwood, *Tehon & Thompson s.n.* (ILLS). Williamson: near Herrin, *Abney & Dillard s.n.* (SIU).

3. *Myriophyllum verticillatum* L. Sp. Pl. 992. 1753. (Fig. 3).

Submerged; stem branched occasionally; leaves in whorls of 4-5, 0.8-4.5 cm long, capillary-pinnate with 9-13 division pairs; emersed leaves, if developed, similar to the submerged; floral bracts whorled, linear, up to 1.5 cm long, deeply pinnatifid with 8-15 pairs of segments; flowers axillary, perfect or unisexual; petals 2.5 mm long, spatulate; stamens 8; fruit ovoid, 2.0-2.5 mm long, 4-sulcate, each section rounded with a shallow concavity on the dorsal surface and a conspicuous beak at the summit.

Habitat.—Shallow waters of ponds, streams, and lakes.

Range.—Nova Scotia to Wisconsin and Minnesota, west to Utah and Idaho, east to Illinois, Indiana, and New York; Eurasia.

Myriophyllum verticillatum may be distinguished readily from the other spe-

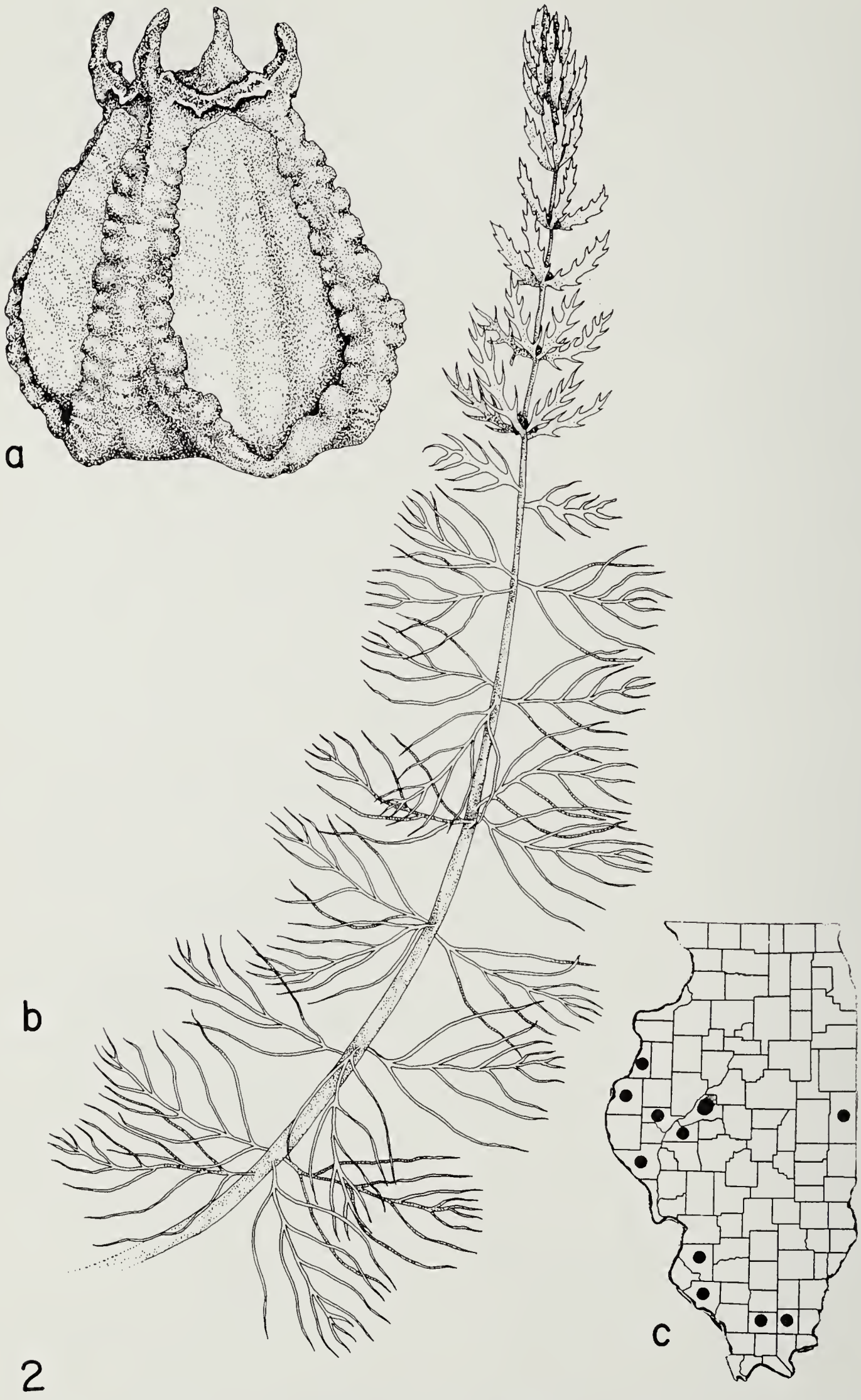

FIGURE 2.—*Myriophyllum pinnatum* (Walt.) BSP. a. Fruit, X 00. b. Plant, X 0. c. Illinois distribution.

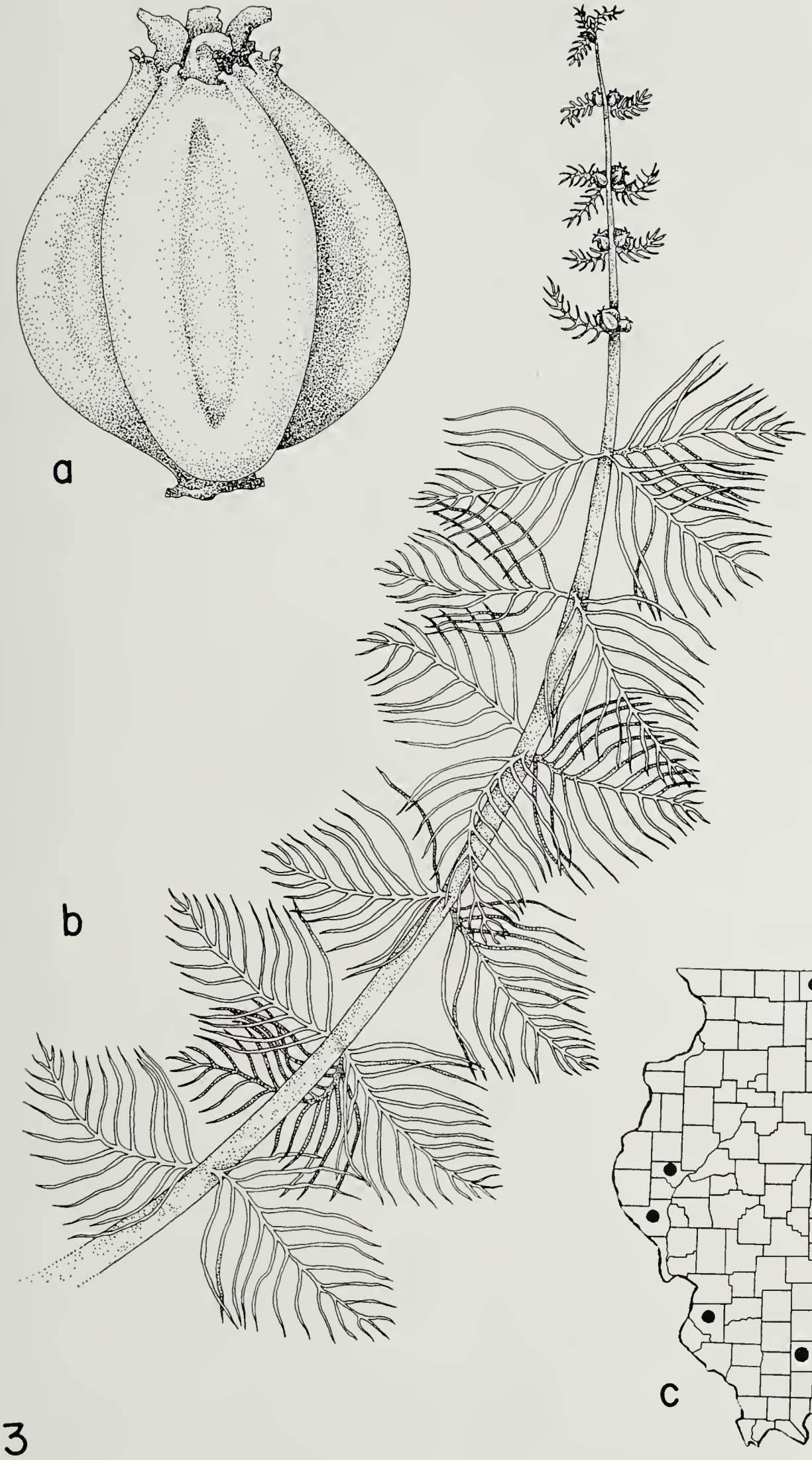

FIGURE 3.—*Myriophyllum verticillatum* L. a. Fruit, X 00. b. Plant, X 0. c. Illinois distribution.

cies on the basis of leaves, bracts, and fruit. The submerged capillary-pinnate leaves are borne only in whorls, unlike the situation in *M. pinnatum*. The bracts are deeply pinnatifid and exceed the flower. The fruit is 4-angled with each section smooth and rounded with a slight vertical concavity on the dorsal margin. A small beak is found at the apex of each section.

Specimens Examined. — Champaign: Crystal Lake, *Clinton 30456* (ILL). Kankakee: Kankakee River, *Hill s.n.* (ILL). Lake: Fox Lake, *Richardson s.n.* (ISM). McHenry: without locality, *Vasey s.n.* (ILL). Pike: W of Hull, *Evers 33335* (ILLS). St. Clair: without locality, *Vasey s.n.* (ILL). Saline: SW of Carrier Mills, *Evers 2787* (ILLS). Schuyler: S of Frederick, *Rexroat 5635* (ISM). Vermilion: Oakwood, *Tehon & Thompson s.n.* (ISM).

4. *Myriophyllum heterophyllum* Michx. Fl. Bor. Am. 2:91. 1803. (Fig. 4).

Submerged; stem occasionally branched; submerged leaves in whorls of 4-6, 2-5 cm long, capillary-pinnate with 7-10 pairs of divisions; emersed leaves few, pinnatifid; floral bracts whorled, oblanceolate to spatulate, 0.4-2.0 cm long, entire to serrate; flowers axillary, perfect or unisexual; petals 1.5-3.0 mm long, acute; stamens 4; fruit subgloboid, 1-2 mm long, deeply 4-sulcate, each section with slightly rounded sides and a dorsal flattened margin with a conspicuous anterior beak.

Habitat.—Ponds, lakes, and still waters of streams.

Range.—Quebec to Ontario and North Dakota, south to New Mexico and Texas, east to Florida; Mexico.

Myriophyllum heterophyllum is characterized chiefly by its floral bracts and fruit. The bracts are oblanceolate to spatulate and the margins entire to serrate. The fruit is distinctly 4-angled and each section has a flattened, smooth dorsal ridge.

Specimens Examined. — Cook: E of Richton Park, *Steyermark s.n.* (ILL). Jackson: N of Murphysboro, *Hardy s.n.* (SIU). Lake: Lake Nippissink, *Thompson & Tehon s.n.* (ILLS). Lee: Amboy, *Long 464* (ILL). McHenry: Ringwood, *Vasey s.n.* (ILL). Macoupin: Carlinville, *without collector* (ILLS). St. Clair: E of E. St. Louis, *Neill 170* (ISM). Vermilion: SE of Oakwood, *Evers 38625* (ILLS). Wabash: Mt. Carmel, *Schneck s.n.* (F). Whiteside: near Meredosia, *Pepoon s.n.* (ILLS).

5. *Myriophyllum exalbescens* Fern. in Rhodora 21:120. 1919. (Fig. 5).

Submerged; stem simple or sometimes branched; submerged leaves in whorls of 3-4, 1.2-3.0 cm long, capillary-pinnate with 6-11 pairs of divisions; emersed leaves, if present, similar to the submerged; floral bracts whorled, spatulate to obovate, up to 3 mm long, entire to denticulate; flowers axillary, perfect of unisexual; petals 2.5 mm long, obovate; stamens 8; fruit ovoid, 2.3-3.0 mm long, 4-sulcate, the sections rounded, smooth to slightly tuberculate and obscurely beaked.

Habitat.—Pools, quiet streams.

Range.—Laborador to Alaska, south to California, Arizona, Kansas, Illinois, West Virginia, and Maryland; Eurasia.

Many American authors have called this *M. spicatum*. Comparison of our material with authentic European material of *M. spicatum* leads us to believe that the two species are distinct.

Myriophyllum exalbescens is recognized by its floral bracts which are shorter than or equal to the length of the fruit. The bracts are spatulate to obovate, entire to slightly toothed. The fruit is 4-angled with a tuberculate surface and no dorsal ridges. The apex is obscurely beaked.

Specimens Examined.—Adams: E of Quincy, *Brinker 2914* (ISM). Boone: NE of Belvidere, *Fell F45441* (ISM). Cook: Des Plaines River, *Fuller 1192* (ISM). Lake: Waukegan Moorland, *Fuller 10549* (ISM). McHenry: Crystal Lake, *Pepoon 6660* (ILLS). McLean: without locality, *Fuller 304* (ISM).

2. *Proserpinaca* L.—Mermaid-weed *Proserpinaca* L. Sp. Pl. 88. 1753.

Only the following species is known from Illinois.

1. *Proserpinaca palustris* L. Sp. Pl. 88. 1753. (Fig. 6).

Submerged or terrestrial; stems prostrate, the branches erect; submerged leaves, if present, alternate, 1-7 cm long. capillary-pinnate to shallowly incised; emersed leaves lanceolate to oblanceolate, 1.5-8.5 cm long, serrate; flowers axillary, solitary or in groups of 2-5, perfect; calyx 3-sided, trilobed; petals 3, minute; stamens 3; fruit pyramidal-ovoid, 3-angled, 3-6 mm long, the surface of each section smooth to tuberculate, the margin slightly winged.

Habitat.—Shallow waters and shores of ponds and lakes.

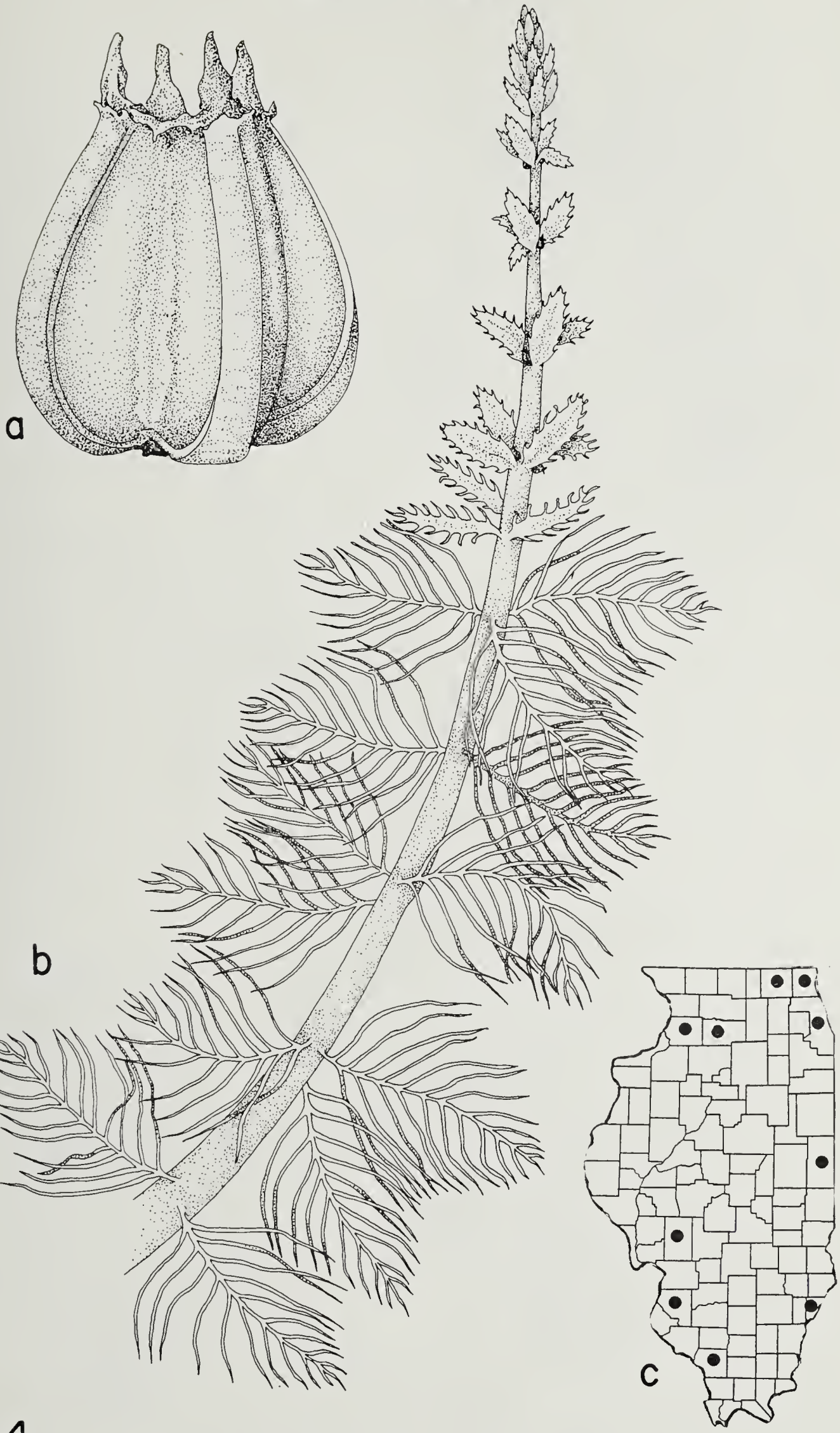

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FIGURE 4.—*Myriophyllum heterophyllum* Michx. a. Fruit, X OO. b. Plant, X O. c. Illinois distribution.

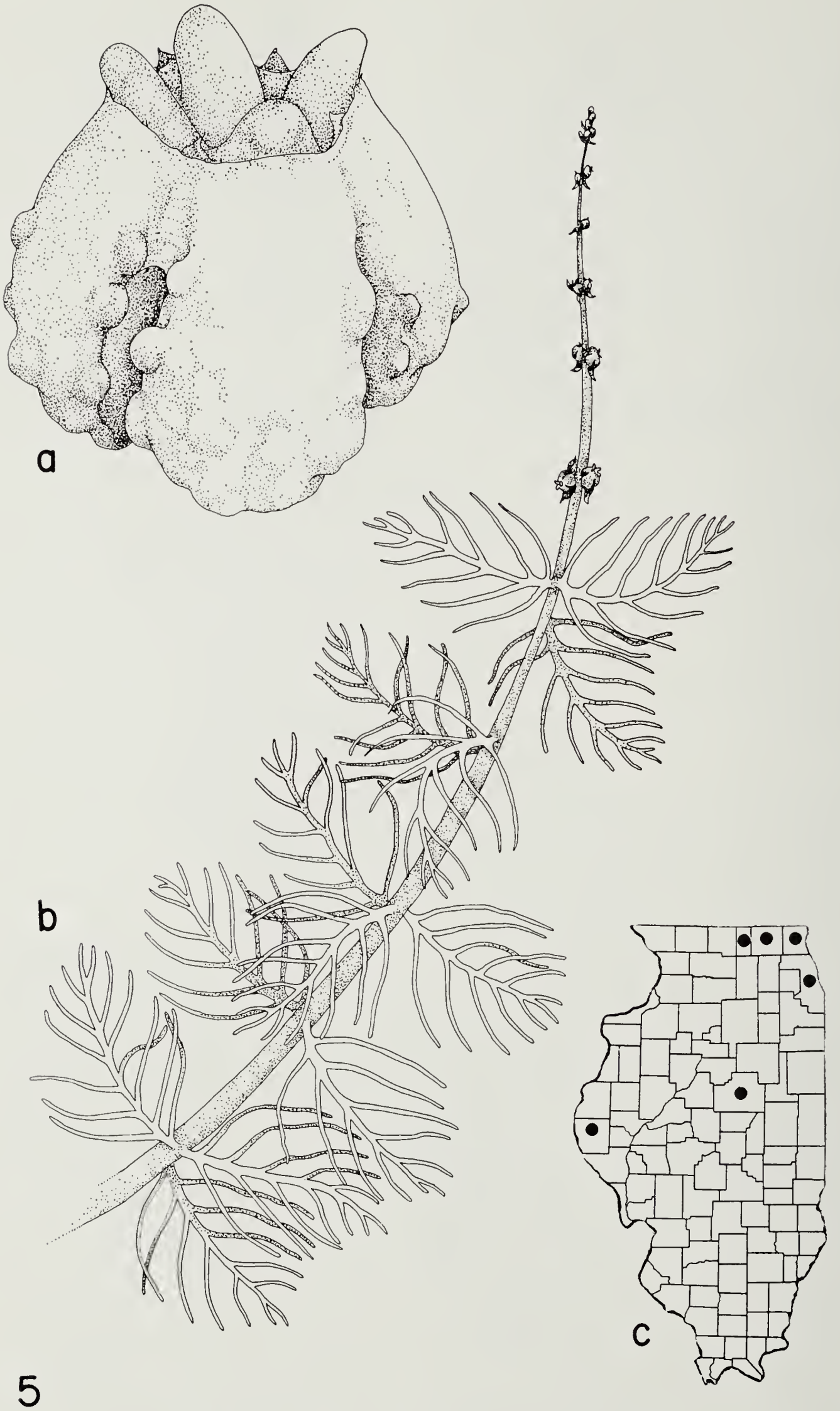

FIGURE 5.—*Myriophyllum exalbescens* Fern. a. Fruit, X 00. b. Plant, X 0. c. Illinois distribution.

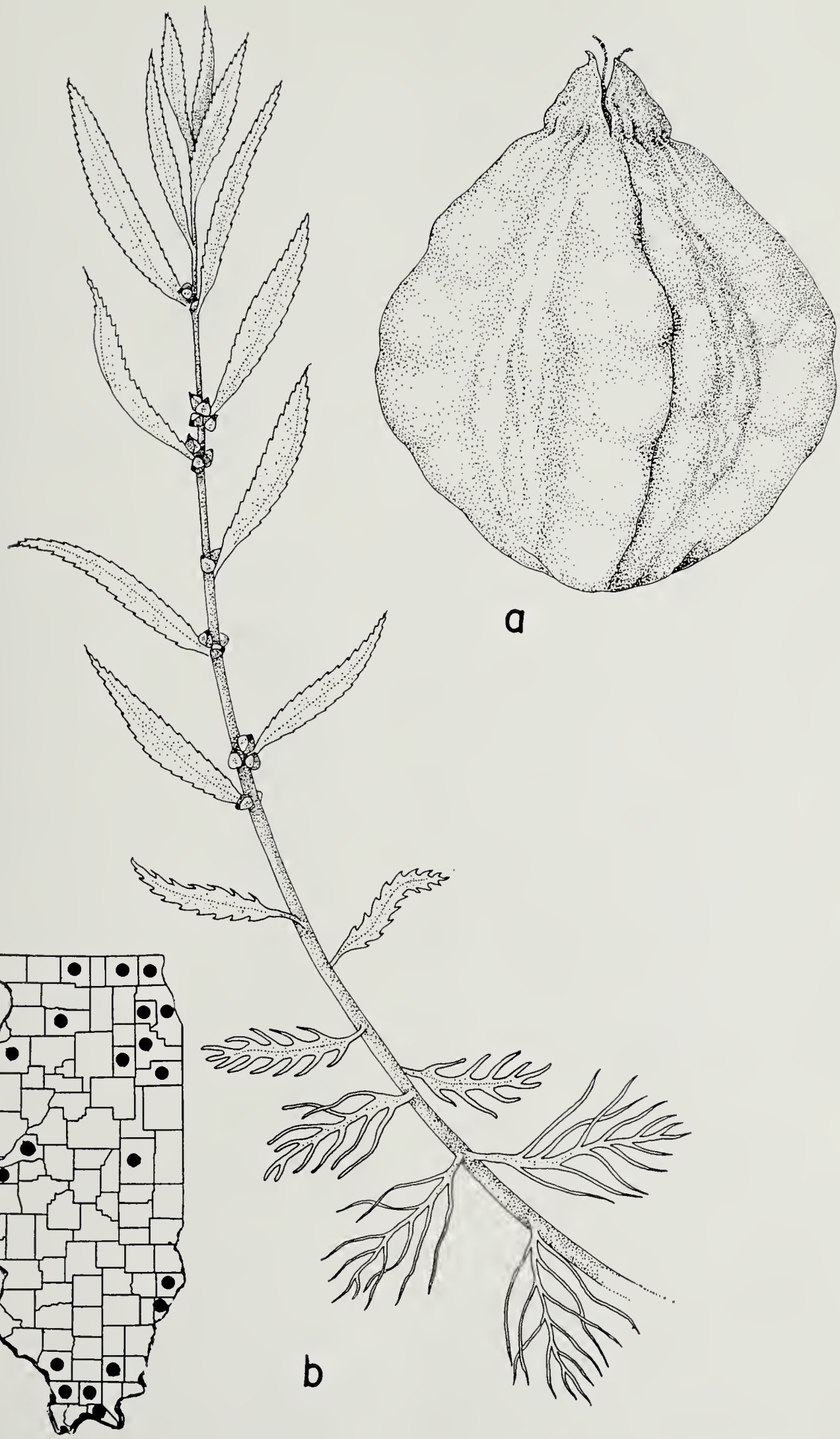

FIGURE 6.—*Proserpinaca palustris* L. a. Fruit, X 00. b. Plant, X 0. c. Illinois distribution.

Range.—Nova Scotia and Quebec to Ontario and Minnesota, south to Louisiana and Florida; Mexico; Central America; West Indies.

Proserpinaca palustris commonly has alternate leaves which are variable: the submerged leaves are pinnatifid, the amphibious leaves, which are found at water level, are deeply toothed, and the emersed, lanceolate leaves are serrate. The flowers are axillary, occurring singly or in clusters of 2-5. The fruit is sharply 3-angled, with each angle slightly winged.

In addition to typical material, Fernald recognizes two varieties with wingless fruits with flat or rounded sides. Neither variety appears to be present in Illinois, although the ranges of each should include Illinois.

Specimens Examined.—Cass: SW of Beardstown, *Winterringer 5219* (ISM). Champaign: Clover Station, *Ahles 2914* (SIU). Cook: Des Plaines River, *Pearsall 7317* (ISM). DuPage: Wheaton, *Blount 56* (ISM). Grundy: NE of Gardner, *Evers 32344* (ILLS). Henry: W of Sedgely Crossing, *Dobbs s.n.* (ILL). Jackson: E of Elkville, *Bailey & Swayne 3103* (SIU). Johnson: E of Vienna, *Hall & Winterringer 25* (ILL). Kankakee: SW of Custer Park, *Steyermark s.n.* (ILL). Lake: N of Waukegan, *Fuller 9049* (ISM). Lawrence: SE of Lawrenceville, *Sivert s.n.* (ILL). Lee: S of Amboy, *Chase 13113* (ILL). McHenry: Ringwood, *Vasey s.n.* (F). Mason: W of Saidora, *Rexroat 6088* (ISM). Massac: E of Brookport, *Bailey & Swayne 2721* (SIU). Saline: Cottonwood Pond, *Bailey & Swayne 2841* (SIU). Union: Wolf Lake, *without collector* (SIU). Wabash: Mt. Carmel, *Schneck s.n.* (F.). Will: SW of Braidwood, *Evers 30851* (ILLS). Winnebago: N of Shirland, *Fell & Fell 46541* (ISM).

Hippuridaceae—Mare's-tail Family

1. *Hippuris* L.—Mare's tail

Hippuris L. Sp. Pl. 4. 1753.

Only the following species occurs in Illinois.

1. *Hippuris vulgaris* L. Sp. Pl. 4. 1753. (Fig. 7).

Submerged; stem erect, unbranched; submerged leaves verticillate, linear to filiform, often reduced to scales; emersed leaves in whorls of 6-12, linear to oblong, 0.4-3.5 cm long, entire; flowers axillary, perfect or unisexual; sepals and petals none; hypanthium enclosing ovary in the perfect flowers; stamen 1; style 1; fruit indehiscent, ellipsoid, nut-like, 1-seeded.

Habitat.—Shores of streams and lakes or in shallow water.

Range.—Greenland to Alaska south to New Mexico, Nebraska, Illinois, Indiana, and New York; Eurasia.

Hippuris vulgaris is characterized by having its entire, linear leaves arranged in whorls of 6-12 on unbranched erect stems. The tiny flowers are axillary in the leaves of the middle and upper portion of the plant. The ellipsoid fruit is smooth.

Specimens Examined.—Kane: South Elgin, *Sherff s.n.* (F). Lake: Grass Lake, *Gleason & Shobe 260* (ILL). McHenry: without locality, *Vasey s.n.* (ILL).

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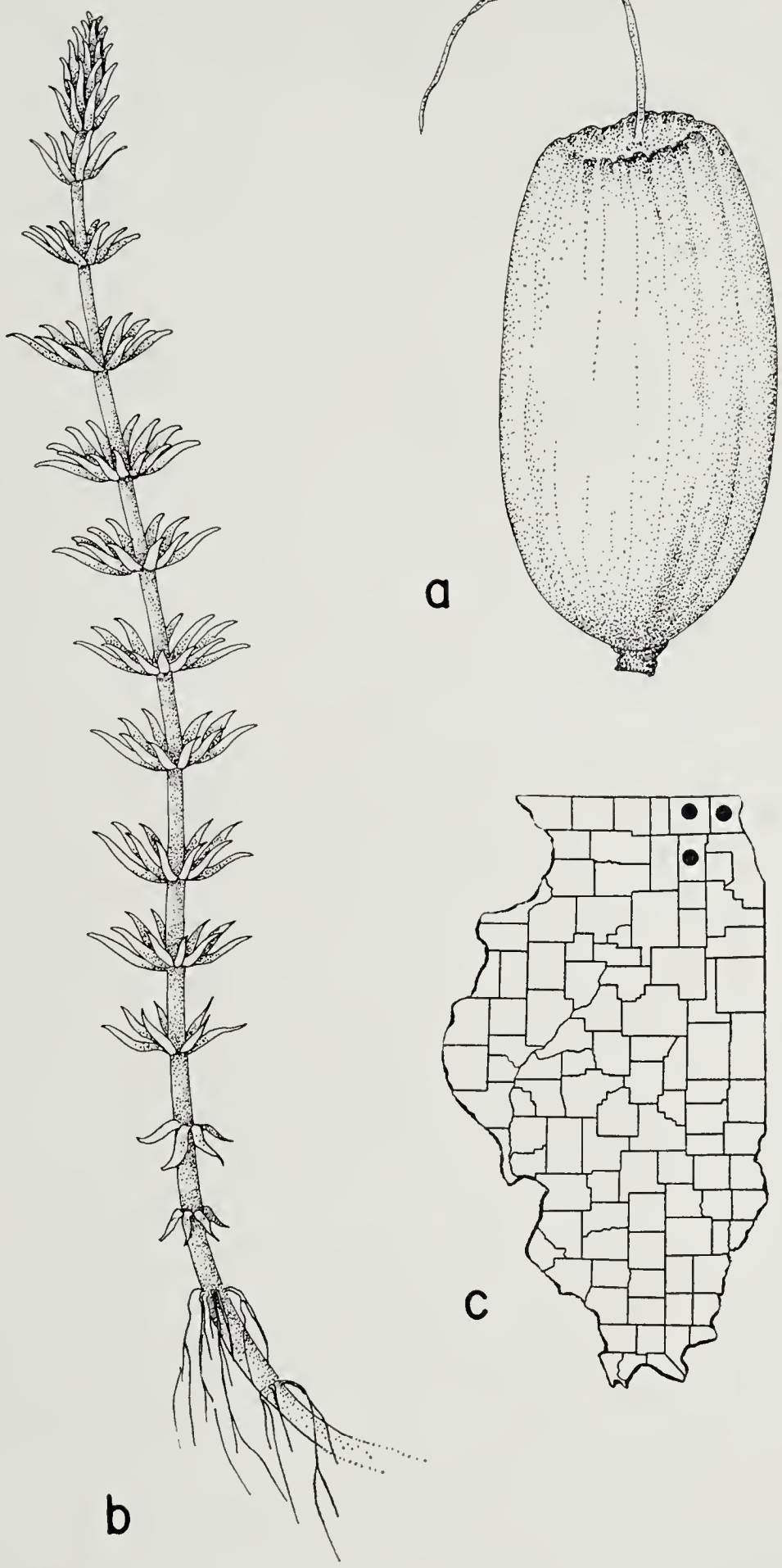

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FIGURE 7.—*Hippuris vulgaris* L. a. Fruit, X 00. b. Plant, X 0. c. Illinois distribution.

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Manuscript received December 1, 1965.

DISTRIBUTION OF LYCAENIDAE (LEPIDOPTERA) IN ILLINOIS

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ABSTRACT.—A list of 27 species of Lycaenidae from Illinois is presented with their county distribution, flight periods, and number of broods per year. Attention is focused on those counties from which few distribution records are known.

The butterfly family Lycaenidae (including the Riodininae) is worldwide in distribution and consists of approximately 7,000 species. These represent nearly half of the described species of the superfamily Papilionoidea. Information on Illinois Lycaenidae is slight and scattered in such works as the summary for the North American collecting season published annually by the Lepidopterists' Society (i.e. Remington, 1948-1951). Worthington (1880) seems to be the only author who has dealt exclusively with the Illinois butterflies. The paucity of records of Lycaenidae from the state led me in 1962 to solicit data on distribution from various collectors. The response to the original survey and the continued help of Illinois lepidopterists has been most gratifying and has been instrumental in the decision of Mr. Roderick Irwin and the author to join forces in a larger work on Illinois Papilionoidea and Hesperioidea. It has also provided incentive to publish this preliminary report on the Lycaenidae, which should facilitate the progress and add to the coverage of the larger study by disclosing those areas where little collecting has been done. The value of critical analysis is often (paradoxically) the elucidation of what is unknown, rather than what is known.

Table 1 is a list of species of Lycaenidae now known to occur in Illinois. None of the species is endemic; all occur in other states. The names follow Ehrlich and Ehrlich (1961). Subspecies names have not been used. An asterisk indicates that the species was also cited by Worthington (1880). In order to better interpret Worthington and perhaps other early papers, it seems advisable to indicate how the early names differ from modern usage. Exclusive of generic assignments, the following differences may be noted (Worthington names first, modern usage last) : *americana* D'Urban=*phleas americana* Harris; *borealis* Gr. & Rob. (*sensu* Worthington *nec auct.*)=*muticum* McAlpine; *dione* Scud.=*xanthoides dione* Scud.; *humuli* Harr.=*melinus humuli* Harr.; *poeas* Hbn.=*cecrops* Fabr.; *pseudargiolus* Bdv. & Lec.=*argiolus* Linn.; *scudderii* Edw. (Illinois records)=*melissa samuelis* Nab.; *smilacis* Bdv. (& Lec.)=*gryneus* Hbn.; *strigosa* (*sic.*) Harr.=*liparops strigosus* Harr.

TABLE 1. Flight Period Data for Illinois Lycaenidae.

Species	Months (by initial)									Estimated No. Broods
	M	A	M	J	J	A	S	O	N	
Callophrys gryneus (Hbn.)*		X	X	X	X					2
C. henrici (Grote & Rob.)	X	X	X							1
C. irus (Godt.)*			X							1
C. niphon (Hbn.)*		X	X							1
C. polios (Cook & Wats.)		X	X							1
Calycopis cecrops (Hbn.)*		X		X		X		X		2+
Celastrina argiolus (Linn.)*	X	X	X	X	X	X	X			2+
Chrysophanus titus (Fabr.)*				X	X	X				1
Euristrymon ontario (Edw.)			X							1
Everes comyntas (Godt.)*		X	X	X	X	X	X	X		3+
Feniseca tarquinius (Fabr.)*		X	X	X	X	X	X			2+
Glaucopsyche lygdamus (Dbldy.)*		X	X							1
Hemiargus isola (Reak.)				X	X	X	X	X		2
Lephelisca muticum (McAlp.)*			X							1
Leptotes marinus (Reak.)							X			1
Lycaena helloides (Bdv.)			X	X	X	X	X	X		2+
L. phleas Linn.*		X	X	X	X	X	X	X		3+
L. thoe Guer.*			X	X	X	X	X	X	X	2+
L. xanthoides Bdv.*				X	X	X				1
Panthiades m-album (Bdv. & Lec.)*		X	X		X	X		X		2+
Plebejus melissa Edw.*			?							1
Satyrium acadica (Edw.)*				X	X	X				1
S. calanus (Hbn.)*			X	X	X					1
S. caryaevorus (McD)					X					1
S. edwardsi (Saund.)*				X	X					1
S. liparops (Bdv. & Lec.)*			X	X	X					1
Strymon melinus (Hbn.)*		X	X	X	X	X	X	X		3+

* Reported by Worthington, 1880.

Flight period data are given in Table 1. Since local conditions may affect adult emergence and longevity in any one area, the flight periods may vary in different populations from north to south or from year to year. Physical factors may also influence the number of broods per year so that the numbers given in Table 1 are only estimates for the multiple-brooded species.

Several species have been collected in only one county. In the case of *caryaevorus, niphon, ontario* and *polios,* captures on two or more dates, or in two or more years, suggest that resident populations are established. More extensive collecting will very probably show each of these species to have a wider distribution in the state. Both the *irus* and *melissa* records stem from single specimens in the collection of the Illinois Natural History Survey. The former species is labeled "Beach" (Illinois Beach State Park, Lake County) while the *melissa* specimen is labeled only "N. Illinois." Although other Illinois specimens referable to these species may eventually be located in private collections, it would appear that both species are considerably rarer than published records might indicate. Both species are given

by Worthington (loc. cit.), and their occurrence in Illinois is mentioned by Klots (1951). In the case of *Plebejus melissa samuelis* Nab., a hasty or careless judgment of the "vic. Chicago" citation by Nabokov (1949) could lead to error. Whereas that author was justified in his citation, and actually gave the Hartman Farm locality from which the original specimens were obtained, the site is in Indiana as Kwiat (1908) makes perfectly clear. On the basis of the single specimen mentioned above, and the possibility of its occurrence in the northeast part of the state, *melissa* is retained in the list and given the same flight period as specimens from Hartman Farm, Hessville, Indiana. This species is also entered as a Cook County record in Table 2 although it may have been taken elsewhere in the northern part of the state.

Table 2 gives the distribution of the species of Lycaenidae by county. County records of and by themselves are not the desired feature; rather, as indicated by their use here, they do serve as an index of geographical coverage, and should provide some valuable information on general distribution. Six of the 102 counties have no lycaenid records and for that reason probably no other records of diurnal Lepidoptera. In addition, 54 counties have only one or two species of lycaenids reported. In fact, were we to take the eastern-tailed blue, *Everes comyntas*, from our data sheets, 31 of our counties would have no lycaenids recorded. This situation is shown graphically in Figure 1, where the concentration of Lepidopterists (and collecting) is reflected by those counties with the largest number of species. Counties with no records, or only *comyntas*, have had the least amount of reported collecting, and future efforts might well be directed toward obtaining specimens in these areas. It is interesting to note that the location of state supported universities (indicated on the map) is not correlated with areas

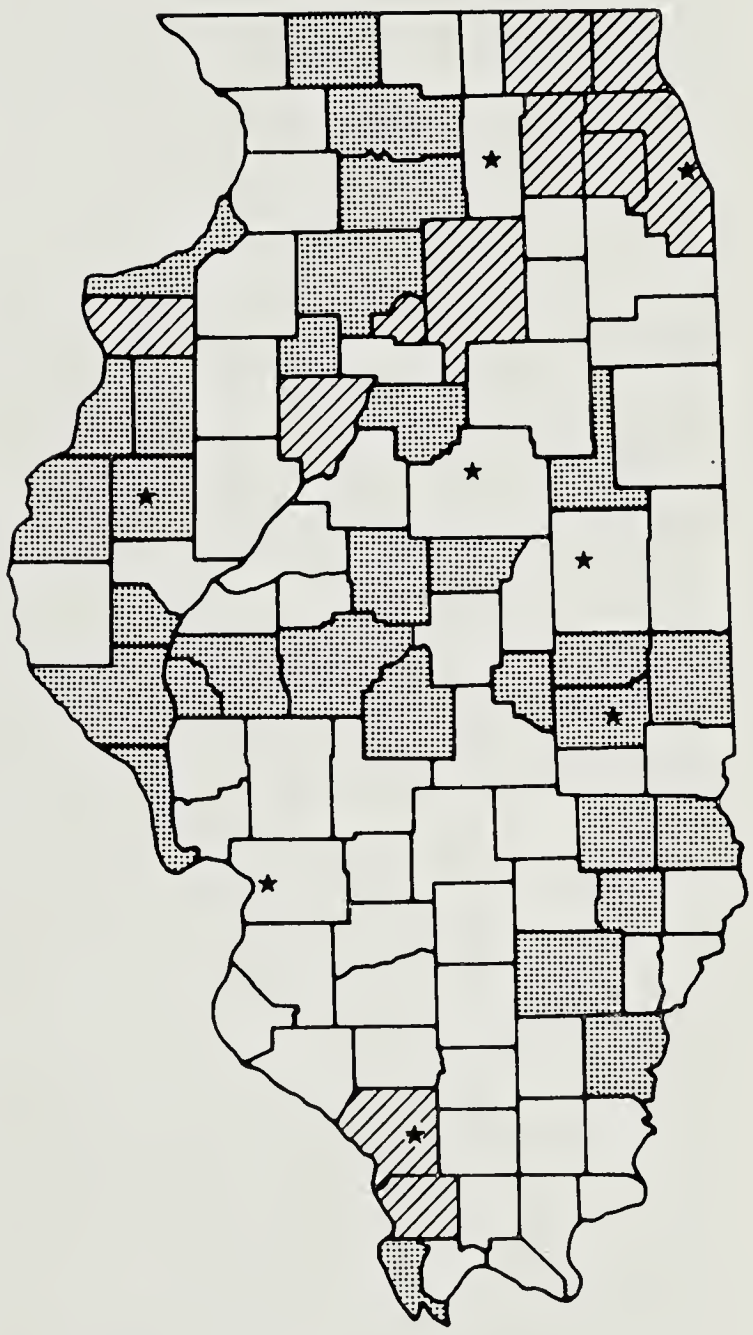

FIGURE 1. Map of Illinois showing counties from which Lycaenidae have been reported. Counties marked with oblique stripes have 10 or more species reported and also have resident lepidopterists. Counties marked with stiples have either no records or only one species (*Everes comyntas*); unmarked counties have two to nine lycaenids in the list. Stars indicate the campuses of state Universities (see text).

TABLE 2.—County Distribution Records of the Species of Lycaenidae in Illinois.

County	acadica	argiolus	calamus	caryaevorus	cecrops	comyntas	edwardsi	gryneus	helloides	henrici	irus	isola	liparops	lygdamus	m-album	marinus	melinus	melissa	muticum	niphon	ontario	phleas	polios	tarquinius	titus	thoe	xanthoides
Adams	.	.	X	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Alexander	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bond	.	X	.	.	.	X	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.
Boone	.	.	X	.	.	.	.	.	X	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.
Brown	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bureau	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Calhoun	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carroll	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.
Cass	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.
Champaign	.	X	X	.	.	X	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	X	.	X	.	X	.
Christian	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Clark	.	.	.	.	.	X	.	.	.	.	.	.	X	.	.	.	X	.	.	.	.	X	.	.	X	.	.
Clay	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.
Clinton	.	X	.	.	.	X	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	X	.	.	.	.	.
Coles	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cook	X	X	X	X	X	X	X	X	X	.	.	X	X	X	X	X	X	X	X	.	.	X	.	X	X	X	X
Crawford	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cumberland	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.
De Kalb	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.
De Witt	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Douglas	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Du Page	X	X	X	.	.	X	X	.	X	.	.	.	X	.	.	.	X	.	.	.	.	.	.	X	X	X	X
Edgar	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Edwards	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.
Effingham	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.
Fayette	.	X	X	.	.	X	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	X	.
Ford	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Franklin	.	X	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.
Fulton	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	X	.	.	.	.	.
Gallatin	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.
Greene	.	.	.	.	.	X	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.
Grundy	.	X	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.
Hamilton	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.
Hancock	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hardin	.	.	X	.	.	X	.	X	.	.	.	.	X	.	.	.	X	.	.	.	.	.	.	.	.	.	.
Henderson	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Henry	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.
Iroquois	.	.	.	.	.	X	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.
Jackson	.	X	X	.	X	X	.	X	.	X	.	.	X	.	.	.	X	.	.	X	X	X	.	.	X	X	.
Jasper	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Jefferson	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	X	.
Jersey	.	.	.	.	.	X	.	.	.	.	.	X	.	.	X	.	X	.	.	.	.	.	.	.	.	X	.
Jo Daviess	.	.	X	.	.	.	.	X	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	X	.
Johnson	.	.	.	.	.	X	.	.	.	X	.	.	.	.	.	.	X	.	.	.	.	X	.	.	.	.	.
Kane	X	X	X	.	.	X	X	.	X	.	.	X	X	X	.	.	X	.	X	.	.	X	.	.	.	X	X
Kankakee	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	.	.	.
Kendall	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.
Knox	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.
Lake	X	X	X	.	.	X	X	.	X	.	X	X	.	X	.	.	X	.	X	.	.	X	X	.	X	X	.
LaSalle	.	X	X	.	.	X	.	X	X	.	.	.	.	.	.	.	X	.	.	.	.	X	.	X	X	X	X
Lawrence	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	X	.	.	.	.	.
Lee	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

TABLE 2.—Continued.

County	acadica	argiolus	calanus	caryaevorus	cecrops	comyntas	edwardsi	gryneus	helloides	henrici	irus	isola	liparops	lygdamus	m-album	marinus	melinus	melissa	muticum	niphon	ontario	phleas	polios	tarquinius	titus	thoe	xanthoides
Livingston		X	X			X									X		X					X		X		X	X
Logan						X																					
Macon						X																X					
Macoupin						X											X					X					
Madison		X				X				X																X	
Marion		X	X			X						X	X				X					X			X	X	
Marshall		X				X											X					X			X	X	X
Mason			X			X	X	X									X					X				X	
Massac						X		X																			
McDonough						X																					
McHenry	X	X	X			X	X		X					X			X		X			X				X	
McLean		X				X																				X	X
Menard						X																X					
Mercer		X	X			X						X	X			X	X					X		X	X	X	X
Monroe						X																			X	X	
Montgomery		X				X																X					
Morgan						X																					
Moultrie						X																					
Ogle						X																					
Peoria		X	X			X		X	X	X			X				X					X		X	X	X	X
Perry						X											X									X	
Piatt			X			X																					
Pike						X																					
Pope		X	X		X	X		X		X							X							X	X		
Pulaski			X			X											X					X				X	
Putnam		X	X			X	X	X		X					X		X					X		X	X	X	X
Randolph						X		X																			
Richland						X																					
Rock Island																											
Saint Clair					X	X				X					X												
Saline		X				X				X							X					X					
Sangamon						X																					
Schuyler						X											X										
Scott																											
Shelby						X																			X	X	
Stark						X																					
Stephenson						X																					
Tazewell																						X					
Union		X			X	X		X		X					X		X					X		X		X	
Vermilion		X				X																					
Wabash						X											X								X		
Warren																						X					
Washington					X	X																					
Wayne						X																					
White						X																					
Whiteside						X																X				X	
Will		X				X																				X	
Williamson		X			X	X											X					X			X	X	
Winnebago																	X									X	
Woodford						X																					

from which we have the greatest amount of information even though some of these institutions have large insect collections, and all have departments offering courses in entomology.

It may be determined from Table 2 that almost half of the lycaenid species in the state are broadly distributed, though not necessarily common. Widespread species include: *argiolus, calanus, comyntas, gryneus, henrici, isola, liparops, m-album, melinus, phleas, tarquinius, titus* and *thoe*. Eleven species have a Northern or North-central state distribution: *acadica, caryaevorus, edwardsii, helloides, irus, lygdamus, marinus, melissa, muticum, polios* and *xanthoides*. Only three, *cecrops, niphon,* and *ontario* appear to be limited to the southern part of the state, and *cecrops* has been recorded once from Chicago (*casual?*).

It is hoped that this list will indicate to the reader that in spite of a rather large number of collectors, the butterflies are not as well known as may people believe, and even the basic questions of "what" and "where" need to be answered. With continued cooperative efforts much can be learned in a relatively short time.

Acknowledgments

I am most grateful to the following people for distributional records: G. L. Adams, R. Arnold, J. L. Boughner, T. G. Brady, M. L. Bristol, H. K. Clench (Carnegie Museum), P. J. Conway, M. Davis, Dr. H. Dybas (Chicago Natural History Museum), M. O. Glenn, R. R. Irwin, D. A. Lawrence, D. Oemick, D. R. Parkinson, L. S. Phillips, Dr. H. H. Ross (Illinois Natural History Survey), L. Schatz, T. Taylor, G. Zelnick, and A. K. Wyatt. Acknowledgement is also made to the National Science Foundation (Grant No. G23560) and to the Graduate School, Southern Illinois University for the support of longer ranged studies of Lycaenidae.

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Manuscript received December 17, 1965.

ANIMAL REMAINS FROM THE STILWELL SITE, ILLINOIS

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Abstract.—The Stilwell Site, located along the Illinois River in Pike County, Illinois, was inhabited by Prehistoric Indians of the White Hall phase of the Late Woodland period, between A.D. 350 and 600. Occupants of this site depended upon animals taken in the Illinois River, its surrounding floodplains and, to a limited extent, the nearby uplands for most of their food. Total lengths of fish were determined to get an indication of the size of fish utilized by the Stilwell Indians. Two bone awls and a fragment of what appears to be a turtle carapace bowl are the only bone artifacts from the site.

The Stilwell Site is located approximately two miles north of Pearl, Pike County, Illinois, on the West side of the Illinois River valley, immediately north of where a small stream enters the valley. The site, presently one-quarter of a mile west of the Illinois River, is above the high water mark at the base of the bluff at the valley margin.

Two radiocarbon dates, determined by the Michigan Memorial Phoenix Radiocarbon Laboratories, Ann Arbor, Michigan, were A.D. 400 ± 120 (M-1263) and A.D. 600 ± 120 (M-1262) (Crane and Griffin, 1964). Struever (pers. com.) has placed Stilwell in the White Hall phase of the early part of the Late Woodland culture. The White Hall phase is characterized by the Apple Creek ceramic series (Struever, pers. com.) which is stylistically closest to, but distinguishable from, the Weaver ceramic series of central and northern Illinois (Griffin, 1952; Struever, 1965). Struever (pers. com.) estimates, by comparison with the similar Weaver phase in the central Illinois valley, that White Hall dates between A.D. 350 and 600.

Twenty-three earth ovens and storage pits were excavated in July 1961, by a field crew under the direction of Stuart Struever of the University of Chicago. Because a road was being built through the site, the Stilwell material had to be removed before construction began. Due to lack of time, the contents of the features were trowel-removed but not screened.

A total of at least 16 species of mussels, 3 of snails, 15 of fish, 5 of turtles, 8 of birds, and 6 of mammals (Table 1) were identified from the recovered faunal material.

Discussion

Mussels. — Thick-shelled forms of a given species of mussel are generally found in large rivers while the thinner shelled forms occur in smaller streams (Parmalee, pers. com.). Thick-shelled mussels were recovered from the Stilwell Site. The types of habitats preferred by these mussels and their thick shells indicate that they were collected

TABLE 1.—Faunal Remains Identified From The Stilwell Site, Pike County, Illinois.

	Total No. Of Ident. Elements	Min. No. Of Individuals	% Of Total Min. No. Of Animals
Molluscs	166	108	47.4%
Fresh-water mussels	163	105	46.2%
Actinonaias carinata, Mucket	37	26	11.4%
Amblema peruviana, Blue-point	44	25	11.1%
Elliptio dilatatus, Spike	42	24	10.6%
Pleurobema cordatum, Small Niggerhead	7	5	2.2%
Lampsilis siliquoidea, Fat Mucket	8	4	1.9%
Lampsilis ventricosa, Pocketbook	4	4	1.9%
Elliptio crassidens, Elephant's Ear	5	3	1.2%
Quadrula pustulosa, Pimple-back	3	3	1.2%
Proptera alata, Pink Heel-splitter	3	2	0.9%
Fusconaia undata, Pig-toe	3	2	0.9%
Cyclonaias tuberculata, Purple Warty-back	2	2	0.9%
Lampsilis fallaciosa, Slough Sand-shell	1	1	0.4%
Ligumia recta, Black Sand-shell	1	1	0.4%
Quadrula metanevra, Monkey-face	1	1	0.4%
Arcidens confragosus, Rock Pocketbook	1	1	0.4%
Anodonta sp. cf. *A. grandis*, Floater	1	1	0.4%
Snails	3	3	1.2%
Campeloma integrum	1	1	0.4%
Pleurocera sp.	1	1	0.4%
Mesodon thyroidus	1	1	0.4%
Vertebrates	371	119	52.6%
Fish	122	70	31.0%
Amia calva, Bowfin	32	15	6.9%
Ictalurus punctatus, Channel Catfish	23	13	5.8%
Ictiobus sp., Buffalofish	27	11	4.9%
Aplodinotus grunniens, Fresh-water Drum	9	6	2.7%
Micropterus sp., Bass	6	6	2.7%
Ictalurus melas, Black Bullhead	3	3	1.2%
Ictalurus nebulosus, Brown Bullhead	3	3	1.2%
Moxostoma sp., Redhorse	4	2	0.9%
Esox sp., Pike or Pikerel	3	2	0.9%
Ictaluridae, Fresh-water Catfish	3	2	0.9%
Lepomis sp., Sunfish	2	2	0.9%
Lepisosteus osseus, Longnose Gar	3	1	0.4%
Ictalurus natalis, Yellow Bullhead	1	1	0.4%
Lepisosteus platostomus, Shortnose Gar	1	1	0.4%
Minytrema melanops, Spotted Sucker	1	1	0.4%
Pomoxis sp., Crappie	1	1	0.4%
Turtles	87	14	6.1%
Terrapene sp., Box Turtle	22	6	2.7%
Chrysemys picta, Midland Painted Turtle	10	3	1.2%
Pseudemys scripta, Red-eared Turtle	41	2	0.9%
Sternotherus sp., cf. *S. odoratus*, Stinkpot	11	2	0.9%
Chelydra serpentina, Snapping Turtle	3	1	0.4%
Birds	21	16	6.7%
Branta canadensis, Canada Goose	3	3	1.2%
Meleagris gallapavo, Turkey	3	3	1.2%
Aix sponsa, Wood Duck	2	2	0.9%
Anas sp., Dabbling Duck Group	7	2	0.9%
Duck, Indetermined	2	2	0.9%
Ardea herodias, Great Blue Heron	1	1	0.4%
Bubo virginianus, Great Horned Owl	1	1	0.4%

TABLE 1.—Continued.

	Total No. Of Ident. Elements	Min. No. Of Individuals	% Of Total Min. No. Of Animals
Fulica americana, American Coot	1	1	0.4%
Tympanuchus cupido, Prairie Chicken	1	1	0.4%
Mammals	142	19	8.4%
Odocoileus virginianus, White-tailed Deer	105	11	4.9%
Ondatra zibethicus, Muskrat	30	2	0.9%
Procyon lotor, Raccoon	3	2	0.9%
Sciurus sp., Gray and/or Fox Squirrel	2	2	0.9%
Geomys bursarius, Plains Pocket Gopher	1	1	0.4%
Homo sapiens, Man	1	1	0.4%
Total Number	538	227	100.0%

from a large river (the Illinois River) rather than from a small stream such as the one entering the river near the site.

Snails. — Three snails were found in the remains. *Campeloma integrum* and *Pleurocera* sp. are aquatic forms and *Mesodon thyroidus* is a terrestrial species. The small number of snails found indicates that they were not important as food items to the Stilwell Site Indians.

Maxwell (1964) states that mollusc shells were used by Late Woodland Indians to make spoons, hoes, beads and gorgets. None of the molluscs from the Stilwell Site were worked by the Indians.

Fishes.—An estimation of the amount of food available to the Indians and an indication of whether or not selection for size was taking place can be found by determining the lengths of the fish from archaeological remains. The total lengths of the fish from the Stilwell Site were estimated by making specific measurements of elements present in the remains. These measurements were compared with the same measurements on bones from fish of known total length by use of an algebraic ratio, $a/b = c/d$, where the numerators of the two fractions are equal to the bone length and the denominators are equal to the total length of the fish (Paloumpis, pers. com.). The size distribution of the five most common fish is given in Table 2. The determined sizes in inches of others are as follows: *Ictalurus melas* (black bullhead), 9.8, 8.3, and 7 inches; *I. nebulosus* (brown bullhead), 6.6, 7.9, and 11.0 inches; *Moxostoma* sp. (redhorse), 17 and 20 inches; *Esox* sp., 18.0 and 34.0 inches; *Lepomis* sp. (sunfish), 4 and 3.6 inches; *Lepisosteus osseus* (longnose gar), 23.8 inches; *L. platostomus* (shortnose gar), 16.6 inches; *Ictalurus natalis* (yellow bullhead), 13.6 inches; and *Pomoxis* sp. (crappie), 11.6 inches long.

Fish were very important in the diet of the Stilwell Indians. They composed 31% of the total minimum number of animals recovered from the site. Seventy-two percent of the fish were over 12 inches in total length. This indicates that the Stilwell Indians were selecting the larger, meaty fish in preference to the small ones. However, the archaeologists may have passed over many of these smaller bones in their excavation of the site thus biasing the sample in favor of the recovery of the large fish remains.

The bowfin, channel catfish, and the buffalofish comprised 56.0% of the total number of fish. All of the species of fish identified in the Stillwell Site remains commonly live in the Illinois River and its backwaters (Starrett and Fritz, 1965). None of the fish remains show evidence of having been worked by man.

Turtles.—Thirteen percent of the 87 shell pieces of the turtles were burned. One fragment of an unidentified carapace was scraped on the inside; this carapace had probably been used as a dish or bowl. The rest of the turtle remains show no signs of having been worked by man. The box turtle, a terrestrial form, and the rest of the turtles, all aquatic forms, are still present near the Stilwell Site.

TABLE 2.—Size Distribution for the Five Most Common Fish From the Stilwell Site, Pike County, Illinois.

	Estimated total length of fish in inches						
	0–5.9	6.0–11.9	12.0–17.9	18.0–23.9	24.0–29.9	30.0–35.9	Total No. Of Fish
Bowfin	.....	2	9	4	.....	.....	15
Channel Catfish	.....	2	1	5	4	1	13
Buffalofish	.....	1	2	3	3	2	11
Fresh-water Drum	.....	.....	1	3	1	1	6
Bass	1	1	4	.....	.....	.....	6

Birds.—Waterfowl constitute 69% of the identifiable avian remains from the Stilwell site. Parmalee (1958) reports that over 70% of the bird remains from Woodland Culture sites in Illinois are Anatidae. This large number of waterfowl is expected because of the proximity of the Illinois Woodland archaeological sites to bodies of water. Since the uplands were only one-half to one mile from the Stilwell site, the Indians also hunted this area for upland game. Although the prairie chicken is now limited to a few local areas in the southeastern part of the state, local populations of this bird probably occurred in prairie areas near the Stilwell Site during its occupation by the Indian. The original wild turkey is extinct in Illinois (Smith and Parmalee, 1955).

Mammals.—Of the 11 deer jaws in the remains, only 3 were complete enough to determine the age of the animal according to aging techniques established by Severinghaus (1949). The ages of the deer were 6 months, 18 months and 18 to 42 months. Since white-tailed deer in Illinois are born in May or June (Hoffmeister and Mohr, 1957), the deer that were aged at 6 months and 18 months probably were killed in November or December. Evidently these people occupied this site at least during the late fall or early winter as is indicated by the ages of these two deer. However, the size of the sample was too small to determine seasonal occupation.

Almost all of the elements of the deer skeleton were represented at the site. It can be assumed from this that these Indians carried the whole deer back to their camp. There were many fragmentary deer bones, many of which were charred. Some of these bones were shattered, possibly for extraction of the marrow. Two fragments were worked into small pointed instruments (awls?) each about two and one-half inches long.

The occipital bone of the skull of one muskrat has two small holes punched through it. The reason for the presence of these holes is not evident.

Of the animals represented by skeletal remains from the Stilwell Site, 86% were directly associated with the river and its valley. This indicates that the residents of this site hunted primarily on the Illinois River and its backwaters for food. Prairie areas were also hunted to a limited extent as is evidenced by the remains of only one prairie chicken. The site was occupied at least during the late fall or early winter, but seasonal occupation cannot be determined.

ACKNOWLEDGMENTS

The author is grateful for the assistance received and loans of comparative materials from the following persons: Dr. Robert D. Weigel, Dr. Andreas A. Paloumpis, and Dr. J. Alan Holman, all of Illinois State University at Normal. Also, Dr. Paul W. Parmalee of the Illinois State Museum verified identifications of the molluscs and gave much technical assistance. Robert J. Harris of Illinois State University at Normal and Edward A. Munyer of the Illinois State Museum gave many suggestions

and advice. Through the courtesy of Stuart Struever of the University of Chicago, the author was allowed to study the Stilwell faunal remains.

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Manuscript received May 5, 1965.

WINTER FOOD OF THE SHORT-EARED OWL, *ASIO FLAMMEUS*, IN ILLINOIS

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ABSTRACT.—A series of 451 pellets and contents of three stomachs of short-eared owls collected in extensively cultivated areas of central Illinois during the winters of 1962-63, 1963-64 and 1964-65 contained remains of at least 1,013 small mammals, 12 birds and a few insects. *Peromyscus* sp. formed the major prey or about 70% of the total minimum number of animals eaten. Additional mammals included *Mus musculus*, *Microtus* spp., *Rattus norvegicus*, *Blarina brevicauda*, *Cryptotis parva* and *Mustela rixosa*. Juncos (*Junco hyemalis*), house sparrows (*Passer domesticus*), horned larks (*Eremophila alpestris*) and a red-winged blackbird (*Agelaius phoeniceus*) were also eaten. The use of pellets in studying food habits is discussed.

Analyses of owl pellets provide information on distribution and abundance of prey species as well as food habits of owls. Occasionally evidence of rare or not easily collected animals is found. The results of an analysis of owl pellet material representing winter food of short-eared owls from five roosting areas in central Illinois (Coles, McLean, and Woodford counties) are reported here. Additional information on food of these owls in this region occurs in reports by Cahn and Kemp (1930) and Graber (1962) who analyzed pellets from Champaign County.

ROOSTS AND PELLET ANALYSIS

Pellet material was collected during the winters of 1962-63, 1963-64 and 1964-65. All roosts were conifers near open fields where corn, soybeans, alfalfa, sweet clover and oats were principal crops. A few fields in each area had been plowed and a few others were in stubble. During the first winter, in Woodford County, one owl habitually roosted in a white spruce in a small cemetery immediately north of Minonk and another in one of a pair of large junipers bordering a small yard in an outlying residential area about a mile to the south. Most pellets from these areas were found beneath the preferred trees. During February and March of the second winter (1963-64), I found pellets under a dozen trees used as roosts by three owls in another cemetery about one mile east of Bloomington, McLean County.

Two additional samples of pellets were analyzed. Although small, they provided useful comparative data. Both were collected by competent, experienced, local birders. One sample, collected on March 1, 1964, represented food of an unusually large flock of short-eared owls that wintered in a small evergreen nursery near Mattoon, Coles County. I counted 40 owls in the area on March 4 but estimates by other observers ranged as high as 150 during mid-December when they first appeared (Irwin, 1964). The other sample, collected on February 1, 1965, came from the Minonk cemetery where I had previously collected; four short-eared owls were seen in and near the cemetery during the winter of 1964-65. Stomach contents of three owls were also analyzed. They were collected (one on November 19, 1960, and two on November 17, 1964) by Paul W. Parmalee and M. K. Hoffman of the Illinois State Museum staff from roosts in fields of corn stubble three and one-half miles east of Minonk. Species identified from bony remains in all pellets and the amounts of material collected from each roost are shown in Table 1.

TABLE 1.—Remains of Vertebrates in Short-eared Owl Pellets from Central Illinois.

PREY SPECIES	Woodford County Minonk Area					McLean County Bloomington Area	Coles County Mattoon Area	TOTALS FROM ALL AREAS
				3½ Miles East Minonk[1]				
	Cemetery (1962-63) 1 Owl	Cemetery (1964-65) 4 Owls	Residential (1962-63) 1 Owl	Nov., 1960 1 Owl	Nov., 1964 2 Owls	Cemetery (1963-64) 3 Owls	Tree Nursery (1963-64) 40-150 Owls	
Cryptotis parva	1					1		2
Blarina brevicauda	1		2			1		4
Peromyscus sp. (Prob. *P. maniculatus*)	208	50	229	1		178	55	721
Microtus sp. (Prob. *M. ochrogaster*)	3	2	10			22	45	82
Microtus pennsylvanicus	7		24			28		59
Mus musculus	24	17	18	1	2	80	1	143
Rattus norvegicus						1		1
Mustela rixosa					1			1
Eremophila alpestris	2		1					3
Passer domesticus	4	1	1					6
Agelaius phoeniceus					1			1
Junco hyemalis	1	1						2
Total Prey Items	251	71	285	2	4	311	101	1,025
No. of Pellets (and fragments)	85(1)	10(18)	56(99)	1	2	71(62)	23(26)	248(206)
Dry weight of pellet material (grams)	267.0	66.4	335.9			373.6	159.5	1,202.4
Ave. weight of entire pellets (grams)	3.12	3.57	3.14			3.49	4.00	
Ave. No. Prey Items per entire pellet	2.85	3.30	2.71			2.80	2.40	

[1] Stomach contents of three owls analyzed as unbroken pellets.

All pellet material was dried at room temperature for several weeks and then weighed. Linear dimensions of unbroken pellets collected in the Minonk cemetery during the first winter were also recorded. Although water content and changes in shape due to weathering, drying, etc. were unchecked, these measurements adequately expressed the more obvious differences in weight and size of the pellets. Each pellet was placed in a shallow tray of water; when soaked, the softened pellet was removed and carefully teased apart with fine forceps and a needle probe. This method is reliable and moistened pellets are easily dissected. Major long bones, skulls and lower jaws of the mammals and/or major skeletal elements of the birds were removed, identified and counted.

Reference skeletons in the Illinois State Museum were utilized in the identification of remains. Meadow voles (*Microtus pennsylvanicus*) were separated from other voles by differences in last upper molars (described by Hoffmeister and Mohr, 1957, p. 129-130). Since size and shape of unbroken adult skulls are the major diagnostic characters, separation of *Peromyscus maniculatus* (prairie deer mouse) from *P. leucopus* (woodland white-footed mouse) and *Microtus pinetorum* (pine vole) from *M. ochrogaster* (prairie vole) proved infeasible; all skulls of these animals were broken and represented varying ages. Prairie deer mice and prairie voles, however, are probably more common in the hunting areas of the owls. While both species were abundantly represented in pellets collected in Champaign County by Cahn and Kemp (1930) and Graber (1962) remains of white-footed mice and pine voles occurred in only a few of the pellets (those collected by Graber).

Computations and Analysis of Data. Two methods of determining relative abundance of prey species in pellet material were used: (1) In establishing the content of entire or unbroken pellets, the completeness of remains was considered; for example, a pellet containing four nearly complete or four complete mouse skeletons, plus an extra lower jaw or a long bone, contained four mice. (2) In an entire batch of both broken and unbroken pellets, the highest total of skulls (occasionally pairs of unmatched maxillary bones counted as single skulls) or lower jaws (left and right counted separately) indicated the minimum number of animals eaten.

Graber (1962), Weller, Fredrickson and Kent (1963) and others have used another computation where the number of pellets containing a certain prey species is divided by the total number of pellets examined, the figure when multiplied by 100 representing a "per cent frequency of occurrence." While probably not as accurate in reflecting species composition of the prey population as a minimum numbers method, the frequency of occurrence method does provide, according to Weller, et al. (1963), an indication of regularity with which an animal was taken. When applied to my data on entire pellets, no significantly different interpretations were noted, but the method should be used with caution for it does not properly include the important contents of broken pellets.

Results and Discussion

Food. The pellets and stomachs contained remains of 1,025 mammals and birds and four or five insects (Table 1). Rodents of at least five species comprised 98.1% of the prey. Of these, white-footed or prairie deer mice (*Peromyscus* sp.) formed the major prey in all areas or about 70% of the total minimum number of animals eaten. Voles (*Microtus* spp.) were also taken in all areas during the three winters but their importance varied from about 3% to 12% of the animals eaten in the Minonk area to over 44% in the Mattoon area where a minor irruption of mouse populations had apparently occurred. House mice (*Mus musculus*) were also taken in all areas and a juvenile Norway rat (*Rattus norvegicus*) was eaten in or near the Bloomington cemetery. A few least shrews (*Cryptotis parva*) and short-tailed shrews (*Blarina brevicauda*) were taken by owls near Minonk and Bloomington and a nearly complete, partially digested carcass of a least weasel (*Mustela rixosa*), a rare mus-

telid in Illinois, was found in the stomach of an owl collected 3½ miles east of Minonk.

Bones of two juncos (*Junco hyemalis*), six house sparrows (*Passer domesticus*) and three horned larks (*Eremophila alpestris*) occurred in pellets collected in the vicinity of Minonk and remains of a redwinged blackbird (*Agelaius phoeniceus*) were found in one owl's stomach. These species occur as fall migrants and/or winter residents in considerable numbers in the area.

Pellets collected in the Minonk cemetery on December 2, 1962, contained traces of a few large grasshoppers and at least two beetles. Vegetable remains included a soybean in a Minonk cemetery pellet, a corn seed in a Bloomington cemetery pellet and 105 seeds of prickly sida (*Sida spinosa*) in a pellet from the Minonk residential area; all were probably being eaten or transported by rodents when ingested by the owls.

Weather, Roost Selection and Prey. Periodic collection of pellets during the first winter near Minonk facilitated association of one owl's roosting habits and catch with changing weather conditions as shown in Figure 1. During one particularly severe period, from January 17 to February 1, when a deep snow cover and extremely low temperatures prevailed, nearly continuous use of one roost (a thickly foliaged spruce) was observed. This shelter-seeking behavior has been discussed by Hendrickson and Swan (1938), Banfield (1947) and Craighead and Craighead (1956, p. 96). The singularly heavy predation on *Peromyscus* that occurred during this period may be related to the observation (cited authors and others) that white-footed and deer mice travel exposed on the surface of a deep snow while voles burrow beneath in relative protection.

Short-eared owls are well known for their predation on *Microtus*

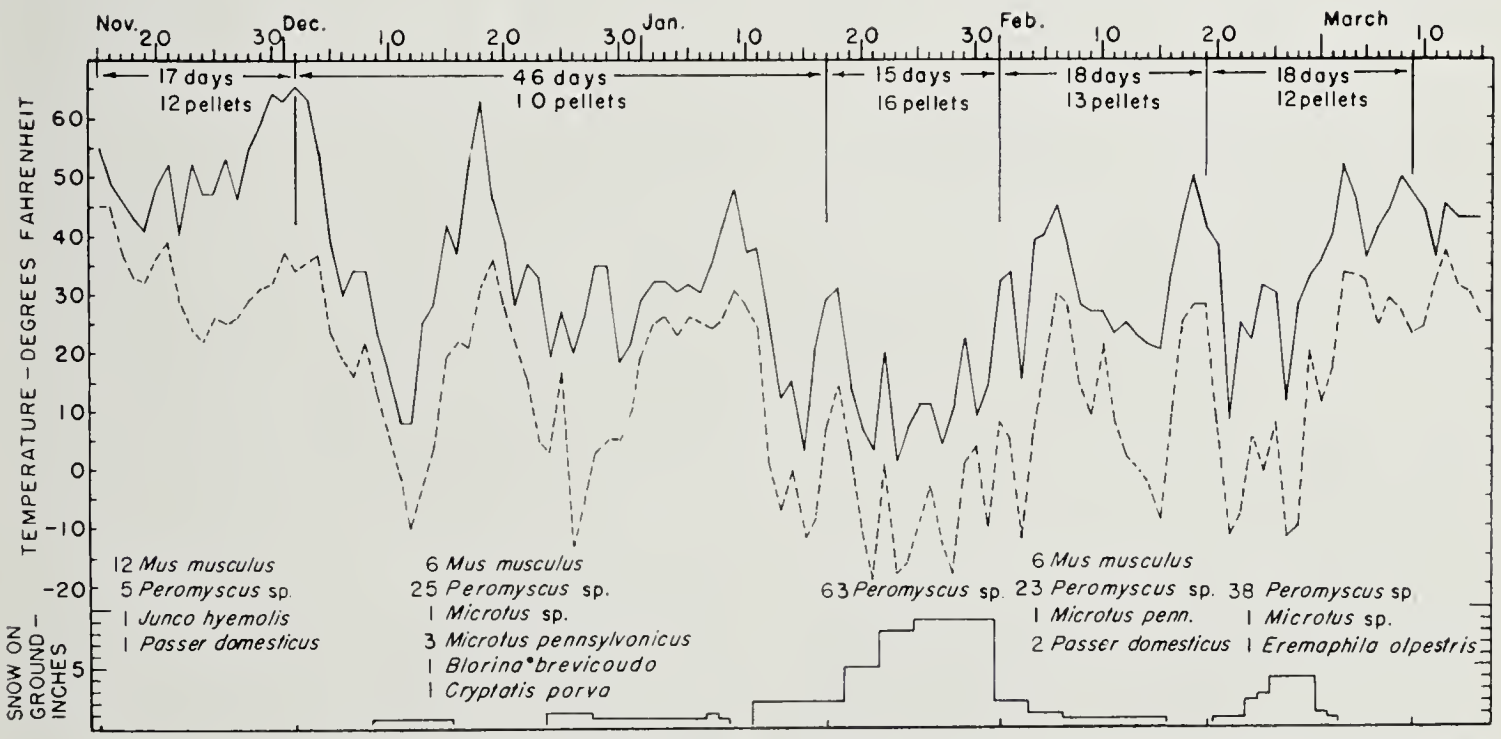

FIGURE 1.—Remains of vertebrates in pellets ejected by one short-eared owl during the winter of 1962-63 in a cemetery near Minonk, Illinois. Of 86 pellets collected, these 63 were found beneath one tree. The solid line represents maximum temperatures and the broken line the minimum temperatures. Depth of snow is also shown.

(Bent, 1938, p. 174; and many others). Therefore the importance of *Peromyscus* in the winter diet of short-eared owls in Illinois as indicated here may be questioned since a higher proportion of *Microtus* might have occurred if pellets ejected in the open fields had been collected. However, pellets collected from open areas in Champaign County by Cahn and Kemp (1930) and Graber (1962) also contained proportionately higher numbers of *Peromyscus* than that commonly recorded from other parts of North America.

Size and Contents of Entire Pellets. Average number of prey items in and weights of unbroken pellets are shown in Table 1. Irregular shapes and compact texture of pellets agreed with descriptions by Stegeman (1957), Reed (1959), Short and Drew (1962) and others. Variation in size was obvious even in small samples of pellets. The average dimensions of the pellets from Minonk were 43.8 mm. by 18.9 mm.; they ranged from 12 to 25 mm. wide and 15 to 84 mm. long. Differences in average number of prey items per pellet depend on size of major prey; where larger prey is involved, averages are smaller (Weller, et al., 1963). The heaviest pellets and those with the lowest average number of prey items were from the Mattoon area where larger mice (*Microtus*) were eaten.

Considering only the smaller rodents (*Mus, Microtus* and *Peromyscus*) as prey items, 39 unbroken pellets from all roosts during all winters contained one, 66 contained two, 52 contained three, 40 contained four, 25 contained five, 4 contained six and 6 contained seven. A few of the pellets containing remains of seven rodents included at least four species. Two of these large pellets contained complete skeletons of seven mice.

Irregularities (missing or extra bones) in short-eared owl pellets have been stressed in many published accounts. While I noted some evidence of this, I found a suprisingly high degree of regularity. The completeness of bony remains (humerii, ulnae, radii, innominate bones, femora, tibiofibulae) in all unbroken pellets suggested that 82% of the mice were consumed in their entirety. If greater care could have been exercised in dissection, the percentage would possibly be even higher. A few radii, ulnae and innominate bones (the latter are unfused in younger mice and hence are occasionally missed) were found after remains of 10 dissected pellets were treated with a potassium hydroxide solution (see Connell, 1962). Extra or missing elements in some pellets are often attributed to the owl's habit of tearing prey apart, but other factors are apparently also involved: Chitty (1938) found small bones sometimes remaining in the stomach after pellet ejection and Short and Drew (1962) observed production of several pellets with irregular contents after a single feeding. Weathering and handling may also cause a loss or gain of bones and further complications arise if parts of broken pellets are counted as entire pellets.

I found no evidence to corroborate the reports by Moon (1940), Kirkpatrick and Conway (1947) and Short and Drew (1962) who found limited amounts of osseous material, extremely efficient bone digestion and

many "thoroughly pulverized" bones, respectively. Working with a captive owl, Chitty (1938) noted a "remarkably low" calcium intake; bone material was well preserved. The bones in pellets of short-eared owls are generally considered an excellent source of data on food habits (Errington, 1930; Craighead and Craighead, 1956; and many others). Differences in age of owls may explain these inconsistent findings. Immature great horned and barred owls, with greater calcium needs, seemingly retain residues of meals for longer periods with a higher level of bone digestion than older birds (Errington, 1930; 1932) and their stomach acidity also differs, being distinctly acidic in younger birds and approaching neutrality in adults (Grimm and Whitehouse, 1963 and cited references).

Analysis of Broken Pellets. Reed (1959) and Short and Drew (1962) suggested that pellets containing *Peromyscus* were not as durable as those with *Microtus,* possibly due to a difference in binding qualities of fur. My observations agree with this but also indicate that pellets containing birds and house mice are likewise more fragile. Broken pellets should be analyzed along with entire pellets for the most reliable data. I found remains of two of the four *Blarina,* one of the two juncos, two of the six house sparrows and one of the three horned larks in broken pellets. Percentages of *Mus* in broken pellets were consistently higher than corresponding figures for entire pellets. In two batches, remains of four species (shrews and birds) were present only in broken pellets. A few workers have rejected broken pellets or have chosen for analysis a sample of pellets (presumably those not broken) from a large batch. This procedure may introduce a bias and considering the many unknown factors already associated with a pellet analysis and its interpretation—a bias of some importance.

Acknowledgments

I wish to extend sincere appreciation to Janet E. Munyer for assistance in the field work; to Dr. and Mrs. Lee Cantwell and Mr. and Mrs. Robert Webster for helpful field observations and pellet samples used during the course of this study; to Mr. Homer C. Parks, United States Cooperative Weather Observer, for providing records; and to Dr. Paul W. Parmalee for suggestions concerning this manuscript.

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Manuscript received August 16, 1965.

CHANGES IN THE LIVERS OF MICE FED POLYOXYETHYLENE SORBITAN DERIVATIVES

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ABSTRACT.—A histochemical and histological study was made of the livers of male and female C57BL/6 mice fed a diet containing 5 or 10% polyoxyethylene sorbitan monolaurate or polyoxyethylene sorbitan monostearate for periods of 10, 18, 29, 34, 54, and 104 weeks. Hepatic focal necrosis and hemosiderosis were the apparent effects of the experimental diets.

A growing number of synthetic surface active agents are currently finding applications in the food industries. Among these, polyoxyethylene sorbitan monolaurate (PSML) and polyoxyethylene sorbitan monostearate (PSMS) have been used. PSML and PSMS are classified as food additives by the U.S. Food and Drug Administration, and have proved to be particularly useful in food processing as emulsifiers.

Several investigations dealing with the hepatic histopathology of these chemicals in various laboratory animals have shown no deleterious effects (Brush et al., 1957; Harris et al., 1951; Chow et al., 1953; Oser and Oser, 1957a). This is compatible with studies relating to the liver when human subjects ingested these and related esters (Kruesi and Van Itallie, 1956; Waldstein et al., 1954). However, in one study the prolonged feeding of a very high concentration of PSMS resulted in possible fatty changes in the liver of some rats (Fitzhugh et al., 1959). In another study, Eagle and Poling (1956) observed diarrhea and liver changes with a highly synthetic diet low in bulk containing PSML.

The present investigation was undertaken to determine the histopathological effects of high dietary levels of PSML or PSMS on the livers of C57BL/6 mice.

METHODS

A local stock of C57BL/6 mice was established and maintained by brother-sister matings. In all cases, mice were weaned at 3 weeks, and then fed Purina Mouse Breeder Chow (fiber content of 2%) in pellet form until 8 weeks old.

Six experiments based upon period of time on a diet were set up: 10, 18, 29, 34, 54, and 104 weeks. Ten control animals (5 males and 5 females) were killed at 8 weeks of age (age of mice at start of each experiment). Except for the 104 week category, mice were randomly divided into groups of 10 each (5 females and 5 males), and were fed either a basal diet of Purina Mouse Breeder Chow in mash form or experimental diets of Purina Mouse Breeder Chow in mash form containing, by weight, 5% PSML or PSMS, or 10% PSML or PSMS. In the 104 week group only female mice were utilized because male mice of the correct age were not available at the time this experiment was initiated.

Mice in each experiment, randomly grouped into five according to sex, were placed in plastic cages provided with perforated steel lid, and wood shavings

for bedding. Animal room temperature was maintained at approximately 25°C. Weekly, each group of 5 mice was placed in a clean cage provided with fresh bedding, clean food receptacle and watering apparatus. Food and water were supplied *ad libitum*.

Routinely, food was removed from the animals 10 hours before killing which took place between 8:00 A.M. and 9:00 A.M. in order to minimize any diurnal variation effect. Mice were killed by a sharp blow on the back of the head. The abdominal cavity was immediately opened, and samples of the anterior region of the median liver lobe were removed rapidly and placed in fresh Carnoy's fixative and 10% neutral formalin.

After fixation the tissue was dehydrated in ethanol, cleared in xylene, and embedded in a mixture of 90% paraffin, 10% bayberry wax at 58°C.

Liver fixed by Carnoy's solution was sectioned at 4 and 7 μ, stained by the periodic acid-Schiff (PAS) technique and counterstained with Mayer's hemalum (Lillie, 1954). Adjacent series of sections of each liver were treated with malt diastase for 45 minutes at 35-45°C. and then stained in the same manner.

Liver fixed by 10% neutral formalin was sectioned at 7 μ, treated according to the ferrocyanide reaction of Perl (Lillie, 1954) and counterstained with safranin 0.

Results and Discussion

Diarrhea was apparent throughout life in mice fed PSML or PSMS, moderate at 10% and slight at 5%. No evidence of tumors or other abnormal growths was found in any animal either during the course of the experiments or at autopsy. No significant abnormalities in behavior or physical appearance were observed in any of the groups.

Wide-spread pericentral infiltration of the hepatic cells by masses of lymphocytes and connective tissue elements was observed (Fig. 1, A and B). In these regions there was an actual destruction of the hepatic cells and their replacement by masses of connective cells on a framework of delicate fibers. The incidence of pericentral infiltration was similar in control and experimental animals. However, the degree of infiltration was greater in the experimental diets.

Among the conditions observed in the hepatic cells was a change which will be referred to as cytoplasmic vacuolation (Fig. 1, C). This was interpreted as fatty change. In all cases the cytoplasm in hepatic cells with vacuolation showed PAS positive material, and vacuolated cells were usually located centrally in the lobules.

At 54 weeks, most of the mice in all experimental diet groups possessed many hepatic cells with very pronounced cytoplasmic vacuolation in all regions, in addition to the central area of the lobules.

Because the cytoplasm of a hepatic cell in normal mice may present a variable appearance that reflects the functional state of the cells, the relationship between PSML or PSMS effects and presence of cytoplasmic vacuolation should be evaluated accordingly. A few experimental animals developed hepatic cell vacuolation a few weeks earlier than the controls. While the incidence of such alterations was similar in control and experimental animals, the extent of vacuolation was greater in the experimental diets.

Significant microscopic observations from mice in all experiments are summarized in tabular form (Table 1).

Necrotic lesions of relatively small areas within hepatic tissues were observed. Necrotic cells were pyknotic and had no detectable glycogen

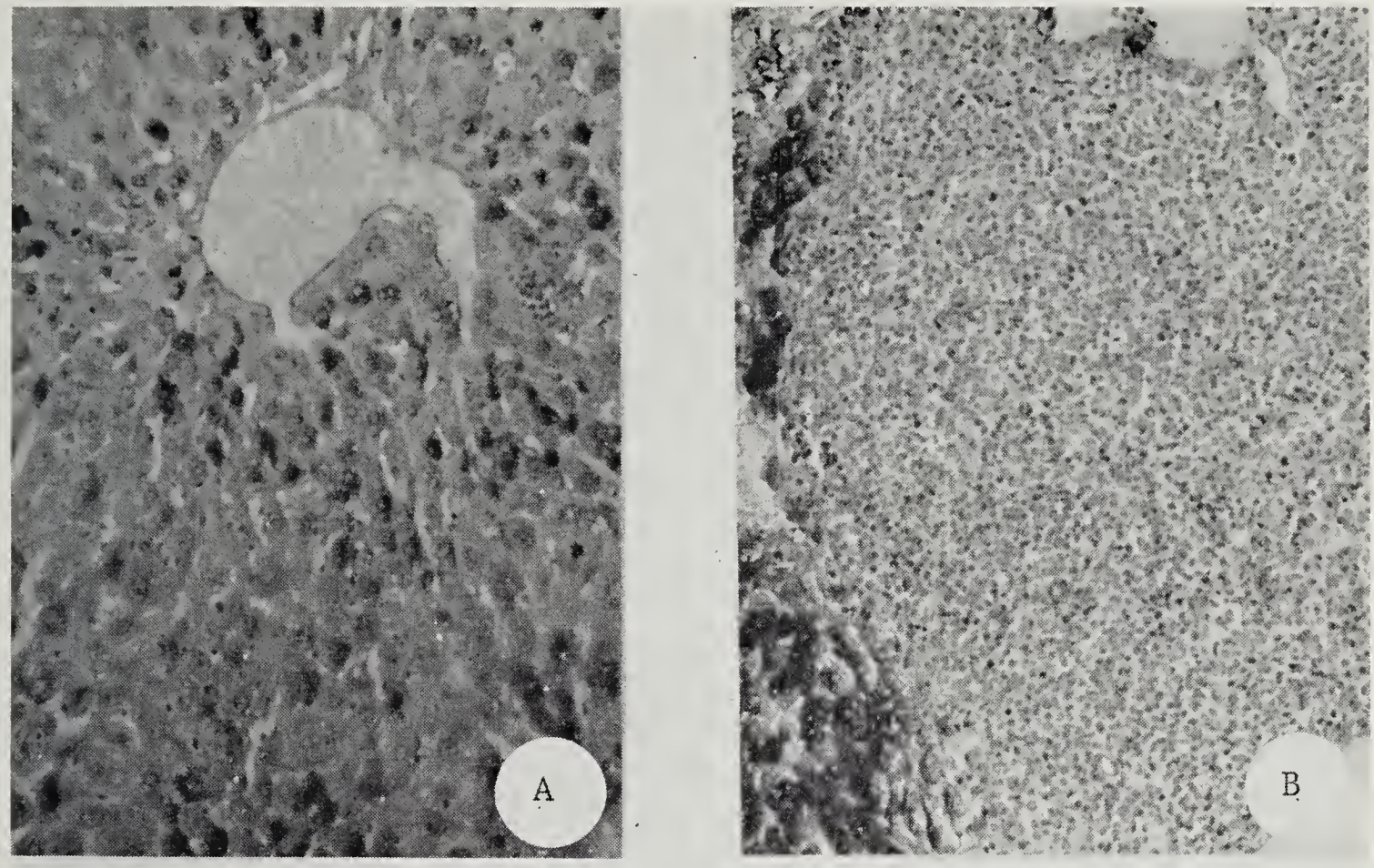

FIGURE 1.—Sections of central vein regions in livers of male mice. Feeding time: 34 weeks. PAS and hemalum. X160. A., control diet; B., PSMS-10% diet, pericentral infiltration; C., PSMS-10% diet, cytoplasmic vacuolation of hepatic cells; and D., PSMS-10% diet, intralobular necrotic lesion.

TABLE 1.—Incidence of Hepatic Histopathology in Mice Fed Polyoxyethylene Sorbitan Monolaurate (PSML) or Polyoxyethylene Sorbitan Monostearate (PSMS).

Histological Finding	Feeding Time (Weeks)[1]	Diets									
		Control		+ PSML, %				+ PSMS, %			
				5		10		5		10	
		M	F	M	F	M	F	M	F	M	F
Necrosis	10	0(5)[2]	0(5)	0(5)	0(5)	0(5)	0(5)	3(5)	4(5)	2(4)	2(4)
	18	0(5)	0(5)	0(4)	0(5)	0(4)	0(5)	2(4)	3(5)	3(5)	4(5)
	29	0(3)	0(5)	0(5)	0(5)	3(5)	3(5)	4(5)	3(5)	2(5)	5(5)
	34	0(5)	0(5)	3(5)	3(4)	4(5)	4(4)	1(5)	4(5)	4(5)	4(4)
	54	1(5)	2(3)	1(3)	5(5)	3(3)	4(5)	4(5)	4(4)	4(5)	4(4)
	104[3]	.....	2(2)	.....	5(5)	.....	4(4)	.....	1(1)	.....	4(4)
Hemosiderosis	10	0	0	0	1	0	2	3	4	2	2
	18	0	0	0	0	0	3	2	3	3	4
	29	0	0	0	2	3	4	4	3	2	5
	34	0	0	0	1	3	4	1	4	4	4
	54	0	0	0	3	0	4	4	4	4	4
	104	.....	1	.....	1	.....	4	.....	1	.....	4

[1] Age of animals in each feeding period equals feeding time plus 8 weeks; 5 male and 5 female control animals (8 weeks old) were negative for all histological findings listed.

[2] Number in parentheses represents number of surviving animals examined at the end of each period.

[3] Only female animals were used at this period.

in the cytoplasm (Fig. 1, D). Often the small areas of necrosis were infiltrated with leucocytes.

The total incidence of animals with focal necrosis of hepatic cells was the following for each diet: (1) control, 5/48 (10%); (2) PSML-5%, 17/51 (34%); (3) PSML-10%, 25/50 (50%); (4) PSMS-5%, 33/49 (67%); (5) PSMS-10%, 38/50 (76%). When the chi square test was applied on these findings, each one of the experimental groups compared to the controls was significantly different ($P<0.05$).

Focal necrosis of hepatic cells appears to be one of the more apparent changes associated with feeding of PSML or PSMS to this specific strain of mice and with this specific diet. This was especially true for animals fed PSMS. Not only was the frequency of hepatic necrosis greater among animals fed PSMS, but the occurrence of necrotic lesions was generally more frequent at shorter feeding periods. While the frequencies in PSML animals exhibiting necrosis of hepatic cells were indicative of an effect, the later appearance of these necrotic regions indicated that PSML was less effective than PSMS in inducing necrosis upon younger tissue.

PSMS and PSML are readily split in the gastrointestinal tract to absorable fatty acids and unabsorbed polyols, which produce diarrhea if present in high levels in rats (Oser and Oser, 1957b). Since in relation to body weight, the mouse eats about three times as much feed as the rat does, and since diarrhea is enhanced with a diet low in fiber, diarrhea in these experimental mice is not unexpected. Although it may not be definitely established, the role of diarrhea was important in the induction of certain hepatic lesions in this strain of susceptible mice.

The total incidence of animals with hemosiderosis of the liver was the following for each diet: (1) control, 1/48 (2%); (2) PSML-5%, 8/51 (16%); (3) PSML-10%, 27/50 (54%); (4) PSMS-5%, 33/49 (67%); (5) PSMS-10%, 38/50 (76%). A chi square test between each experimental group and controls indicated a significant difference ($P<0.001$) for PSML-10%, PSMS-5%, and PSMS-10%.

In all cases the bile ducts, branches of the hepatic artery, and interlobular veins appeared histologically normal. Although there was some increase in connective tissue elements in livers showing infiltration, in no case did the amount of infiltration approach that characteristic of a cirrhosis.

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Manuscript received January 3, 1966.

EFFECT OF ANTIMETABOLITES, PYRIDINE DERIVATIVES, METALLIC SALTS AND INTERMEDIARY METABOLITES ON RAT DIAPHRAGM METABOLISM

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ABSTRACT.—Rat hemidiaphragms have been incubated with a variety of compounds, including antimetabolites, amino acids, pyridine derivatives, intermediary carbohydrate metabolites and inorganic salts in a saline-phosphate medium containing 120 mg glucose per 100 ml and the mean differences in oxygen and glucose uptakes and in glycogen content ascertained. Several of the agents depressed respiration and the glycogen content was diminished in the presence of guanidine•HCl (up to 3.00 mg), imidazole (0.50 mg) and dehydracetic acid (1.00 mg). Glucose uptake was depressed by high levels of sulfanilic acid, elaidic acid, oxalate, phenylpyruvate and citrate. Of a number of inorganic salts, only sodium fluoride at 2.4 μmole caused decreases in both oxygen uptake and glycogen turn-over and these depressions were no longer evident with 0.48 μmole.

The isolated rat diaphragm constitutes an invaluable tissue for the study of muscle carbohydrate metabolism. Among others, the diaphragm has been used to investigate insulin (Gemmill, 1940; Stadie and Zapp, 1947), sulfhydryl compounds Spencer and Gershbein, 1964), vitamins (Gershbein et al., 1964; Gershbein, 1965a) and thyroid hormones (Gershbein, 1965b). In the present investigation, the effect of growth factors, antimetabolites, various pyridine derivatives and analogs, amino acids and metallic ions on the respiration, the glucose uptake and the glycogen content of the rat diaphragm was ascertained. Several carboxylic acids and tricarboxylic acid cycle components were likewise screened. In this conjunction, the utilization of acetate and pyruvate by normal and diabetic rat diaphragms has been reported and except for aconitate, pyruvate metabolism was little influenced by oxaloacetate, α-ketoglutarate or succinate; the incorporation of pyruvate carbon into Krebs' cycle acids was also determined (Villee and Hastings, 1949; Foster and Villee, 1957). The uptake and partition of palmitate-1-C^{14} by diaphragm has been investigated by Shtacher and Shafrir (1963).

MATERIALS AND METHODS

All compounds were obtained from commercial sources and were of high or A.R. purity. Coramine (Ciba) was used in 25% aqueous solution. With the organic acids, either the salts as such or the acids neutralized with aqueous sodium hydroxide were diluted with saline. Incubation was carried out in the phosphate-saline medium of Stadie and Zapp (1947), the concentration of glucose being 120mg/100 ml.

Male Holtzman rats weighing 135-170 g were starved for 16 hr, sacrificed by decapitation and the hemidiaphragms were rapidly removed and introduced

into chilled saline. They were trimmed, blotted between filter paper and the weighed tissues placed in Warburg flasks containing the appropriate media. The latter contained 1.0 ml of double strength Stadie and Zapp medium and 1.0 ml saline as such (control) or 1.0 ml saline solution plus the given test compound (treatment). Control flasks without tissue were also included in each run. The flasks were gassed with pure oxygen and incubated at 37.5 C for 1 hr, after which time the supernatant fluids and the hemidiaphragms were analyzed for glucose and glycogen, respectively. The processing of the tissues and the analytical procedures employed in the method of paired hemidiaphragms have been described in detail in an earlier report (Gershbein, 1965b).

Results and Discussion

Mean differences in Q_{O_2}, glucose uptake and glycogen content of hemidiaphragms incubated with several antimetabolites, acids and metabolic intermediates are presented in Table 1. Oxygen uptake was significantly influenced by desoxypyridoxine•HCl (0.75 mg), isoascorbic acid (1.00 mg), α-methyl-DL-methionine (1.00 mg), 2, 6-diaminopurine sulfate (0.-25 mg) and guanidine•HCl (up to 3.00 mg) to the exclusion of any effect on the glucose uptake or glycogen content except for decreases in glycogen turn-over with guanidine as was also the case with imidazole (0.50 mg). At high levels of sodium oxalate, elaidic acid and phenylpyruvate, both the glucose uptake and Q_{O_2} were decreased. With dehydracetic acid at 1.00 mg, the glycogen content and respiratory activity fell but the decreases did not occur at the lower concentration (0.10 mg).

With the tricarboxylic acid cycle intermediates, respiration of hemidiaphragms was in the direction of stimulation, the increases being definite with α-ketoglutarate, succinate and oxaloacetate but not significant with citrate although the latter agent depressed glucose uptake. In contrast to phenylpyruvate which plays a prominent role in phenylketonuria, pyruvic acid at a high level was without any real effect on the diaphragm. The general antagonistic action of malonate was reflected by an inhibition of respiration.

For the majority of agents screened, the mean differences engendered in Q_{O_2}, glucose utilization and glycogen turn-over were not significant. The compounds together with the respective levels in mg, are listed below:

Adenosine (0.25)
4-Aminobutyric acid (1.00)
2-Amino-4-methylpyrimidine (0.35)
2-Amino-3-phenylbutanoic acid
L-Arginine•HCl (3.00)
Benzimidazole (0.25)
Caffeine (0.50)
Canavanine sulfate (0.50)
Coramine (0.50)
Desthiobiotin (0.35)
Dihydroxyacetone (1.00)
3,4-Dihydro-2H-pyran-2-carboxylate
DL-Ethionine (3.00)
Fumaric acid (1.00)
6-Hydroxynicotinic acid (0.50)
Indole (0.25)
3-Indoleacetic acid (0.50)
Isonicotinic acid (0.75)
Methanesulfonylcholine chloride (0.50)
Nicotinuric acid (0.50)
Oxythiamine·HCl (0.50)
Phosphoenol-pyruvic acid (cyclohexyl ammonium salt; (0.50))
Phosphorylcholine chloride (1.00)
α-Picolinic acid·HCl (0.35)
Pyridine-3-acetic acid (0.50)
Pyridine-3-sulfonic acid (0.50)
DL-Serine (3:00)
Sodium acetate (3.00)
Sodium cholate (0.75)
Sodium cyclohexylsulfamate (sucaryl sodium; (3.50))
Sodium formate (0.50)
Sodium isethionate (0.50)
Sodium pantoyltaurine (0.50)
Sodium propionate (3.00)
Tartaric acid (2.00)
β-2-Thienylalanine (0.50)
Uracil (0.25)

TABLE 1.—Mean Differences in Diaphragm Oxygen Uptake, Glucose Utilization and Glycogen Content in the Presence of the Test Agents[1,2].

Compound (mg)	Mean Q_{O_2} Change		Mean Glucose Difference[3]		Mean Glucose Difference	
	μl/mg wet tissue/hr	t	μg/mg wet tissue/hr	t	μg/mg wet tissue/hr	t
Desoxypyridoxine·HCl (0.75)	0.22 ± 0.049 (12)	4.48**	0.73 ± 0.457 (15)	1.61	0.13 ± 0.087 (15)	1.45
Isoascorbic acid (1.00)	0.14 ± 0.052 (16)	2.63*	0.26 ± 0.230 (11)	1.11	0.01 ± 0.114 (16)	0.09
Imidazole (0.50)	—0.02 ± 0.031 (26)	0.62	—0.30 ± 0.616 (21)	0.48	0.21 ± 0.067 (26)	3.07**
L-3-Aminotyrosine·HCl (1.00)	0.25 ± 0.067 (11)	3.79**	0.26 ± 0.360 (11)	0.72	0.14 ± 0.104 (12)	1.30
α-Methyl-DL-methionine (1.00)	0.10 ± 0.040 (11)	2.42*	—0.11 ± 0.370 (9)	0.31	—0.03 ± 0.050 (11)	0.38
Guanidine·HCl (3.00)	0.22 ± 0.070 (23)	3.10**	.....	.....	0.30 ± 0.069 (20)	4.30**
2,6-Diaminopurine sulfate (0.25)	—0.20 ± 0.020 (11)	9.85**	1.39 ± 1.327 (12)	1.04	0.04 ± 0.081 (11)	0.32
Dehydracetic acid (0.10)	—0.18 ± 0.139 (12)	1.30	0.00 ± 0.447 (11)	0.01	0.22 ± 0.140 (12)	1.60
Dehydracetic acid (1.00)	0.36 ± 0.098 (12)	3.67**	0.15 ± 0.447 (11)	0.34	0.25 ± 0.072 (12)	3.44**
Sulfanilic acid (1.00)	0.10 ± 0.070 (11)	1.40	1.01 ± 0.290 (10)	3.50**	—0.06 ± 0.059 (11)	1.00
Oxalic acid (1.40)	0.13 ± 0.051 (10)	2.50*	0.85 ± 0.330 (12)	2.60*	—0.02 ± 0.230 (11)	0.10
Elaidic acid (0.75)	0.49 ± 0.114 (12)	4.25**	1.36 ± 0.118 (12)	11.57**	0.02 ± 0.058 (10)	0.37
Phenylpyruvic acid (0.90)	0.25 ± 0.082 (14)	2.98**	1.57 ± 0.731 (11)	2.15*	0.12 ± 0.108 (13)	1.09
α-Ketoglutaric acid (1.00)	—0.11 ± 0.047 (13)	2.41*	—0.16 ± 0.390 (12)	0.40	0.11 ± 0.079 (14)	1.41
Succinic acid (1.00)	—0.11 ± 0.037 (13)	2.83*	—1.00 ± 0.632 (14)	1.58	0.07 ± 0.134 (14)	0.51
Citric acid (0.75)	—0.01 ± 0.017 (8)	0.17	0.82 ± 0.311 (18)	2.65*	0.08 ± 0.100 (17)	0.76
Pyruvic acid (0.80)	—0.06 ± 0.064 (21)	0.98	0.92 ± 0.600 (21)	1.53	—0.05 ± 0.046 (22)	1.02
Oxaloacetic acid (1.00)	—0.17 ± 0.045 (25)	3.85**	0.13 ± 0.556 (22)	0.22	—0.11 ± 0.078 (26)	1.45
Malonic acid (1.20)	0.18 ± 0.061 (23)	2.87*	0.65 ± 0.380 (18)	1.67	0.14 ± 0.087 (18)	1.58

[1] The means (± S.E.) are deduced from the number of paired hemidiaphragms specified in the parentheses.
[2] A negative mean value is indicative of an increase in response in the presence of test compound.
[3] Based on the final concentration of the respective media incubated without tissue.
** $P < 0.01$.
* $P < 0.05$.

Serotonin creatinine sulfate (1.00)
Tryptamine·HCl (1.00)
Tyramine·HCl (1.00)

Glucose utilization was not ascertained with the last three compounds.

The effects of a number of inorganic ions were also investigated in relation to diaphragm oxygen uptake and glycogen. Of these compounds, sodium fluoride at 0.10 mg (2.4 μmole) depressed both. The results were negative with fluoride at 0.48 μmole as well as with the following, the concentrations being expressed as micromoles: sodium tetraborate (10.0), cesium chloride (1.5), lithium chloride (11.9), stannous chloride (1.6), aluminum chloride (2.3), didymium chloride (2.0), lanthanum chloride (2.0), rubidium chloride (4.1), strontium chloride (3.2), barium chloride (1.2), zinc chloride (1.8), sodium iodide (1.7), sodium thiocyanate (6.2), and sodium cyanide (2.0). It might be pointed out that Shaw and Stadie (1957) observed a reduction in lactic acid formation from glucose by the diaphragm in the presence of fluoride, a known inhibitor of glycolysis.

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Manuscript received November 10, 1965.

NEWS AND COMMENTS

The last issue of volume 58 got tangled in the Christmas mail rush; so before the end of this year our issues will start coming out at the first of the month.

Again may I call your attention to "Notes". A paper submitted for that section goes into the current issue being prepared for the printer—providing it is acceptable. I must ask that an author indicate that the paper is intended for the "Note" section. The purposes of "Notes" are multifold. Here is a place for the truly short paper as well as some not so short. I admit that my definition of a "Note" is rather flexible. Most important, however, is the intent to have the "Notes" as a place where the neophyte can publish and see the reward of his efforts appearing without a long and agonizing delay. This means a lot to the idealistic, misty-eyed graduate students who want to make contributions to science.

This is a good place to repeat another piece of information. One does not need to present a paper at an annual meeting of the Academy in order to get it printed. All that is required is that the author be a member of the Academy. I should add that I have the liberty to invite non-members to submit papers when I deem them appropriate for publication by our journal.

Regardless of what was said above, I am not trying to sabotage the Annual Meeting. We want papers to be presented at the Annual Meetings. I am ready to grant priority to such papers. In this issue you can read papers that you heard at Normal in April.

New members are coming in by the dozens. Let us make this a record year. I'll send application blanks to anyone who has an interest in science—amateur, teacher, professional, student, or undecided.

Dr. Harlow B. Mills, Chief, Illinois Natural History Survey, Urbana, is retiring after 19 years of service as Chief, effective September 30, 1966.

Dr. Mills, a native of Iowa, received his early education in the public schools of LeGrand, Iowa, and attended Iowa State University at Ames where he earned Bachelor's, Master's and Ph.D. degrees. His professional experience included positions as assistant professor of entomology at Texas A. & M. College, ranger-naturalist and wildlife technician in Yellowstone National Park, assistant state entomologist of Montana and head of the Department of Zoology and Entomology at Montana State College.

Dr. Mills serves as a scientific consultant for several magazines and was editor or the Journal of Wildlife Management from 1947 to 1949. He is a member of several honorary and professional societies in the science and wildlife fields. He has pub-

lished numerous scientific articles on subjects pertaining to entomology and wildlife.

John C. Watson, Director of the Department of Registration and Education, has announced that the Board of Natural Resources and Conservation has approved the appointment of a committee to seek a replacement for Dr. Mills.

NOTES

DEMOUNTABLE CELL HOLDER ADAPTER FOR BROKEN INFRARED SALT WINDOWS

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ABSTRACT. — Recovery and continued use of broken demountable salt windows for infrared spectroscopy are possible through use of a readily constructed demountable cell holder adapter.

One of the problems frequently encountered by infrared spectroscopists employing demountable cells, particularly with the nujol mull technique, is that of broken sodium chloride cell windows. Such windows are moderately expensive and have been essentially useless when broken. The adapter herein described permits recovery and much extended useful life of broken salt windows.

DESCRIPTION

The adapter is constructed from stainless steel, cut from either 3/16-inch plate or 3-inch diameter bar stock. The adapter consists of two plates, a 1½-inch square base plate mounted directly over the shoulders of the conventional demountable cell holder lugs and an upper plate used instead of the demountable cell holder cover plate. The dimensions of the adapter are shown in Figure 1. The location of the rectangular light-path holes must coincide with that of the particular demountable cell holder employed. Appropriate modification must be made for cell holders with three mounting lugs, rather than four. Although the two plates may be mirror images of each other, except for the difference in diameter of the mounting holes, it is convenient to make the base plate substantially larger than the cover plate, so that the demountable cell may be assembled quickly and accurately.

APPLICATION

Broken sodium chloride salt windows must be trimmed to the rectangular dimensions required to fit the adapter—approximately ⅜ x ¾ inches. This may be readily accomplished with an ordinary single-edge razor blade. Thus, at least one, and sometimes two, usable windows may be obtained from each broken window, since the frequently employed circular windows usually break near the center.

Rectangular gaskets approximately ⅜ x 1 inches are also fabricated for use with the reshaped cell windows. These are conveniently cut from polyethylene film — the authors use discarded polyethylene film gloves for this purpose.

An adapter of the type described has been used in the authors' laboratory for nearly a year by beginning and advanced students, as well as by more experienced infrared research workers. In general, the adapter has proved convenient to use and the rather small cell windows resulting from the previously described trimming have not seemed excessively difficult to handle. At the same time, a considerable saving in expenditures for new cell windows has been effected.

ACKNOWLEDGMENT

The authors are grateful to the Cooperative Research Program in Chemistry of the Carbondale Campus of Southern Illinois University and to the Society of the Sigma Xi for grants which supported much of the experimental work involved in testing the adapter described.

Manuscript received November 12, 1965.

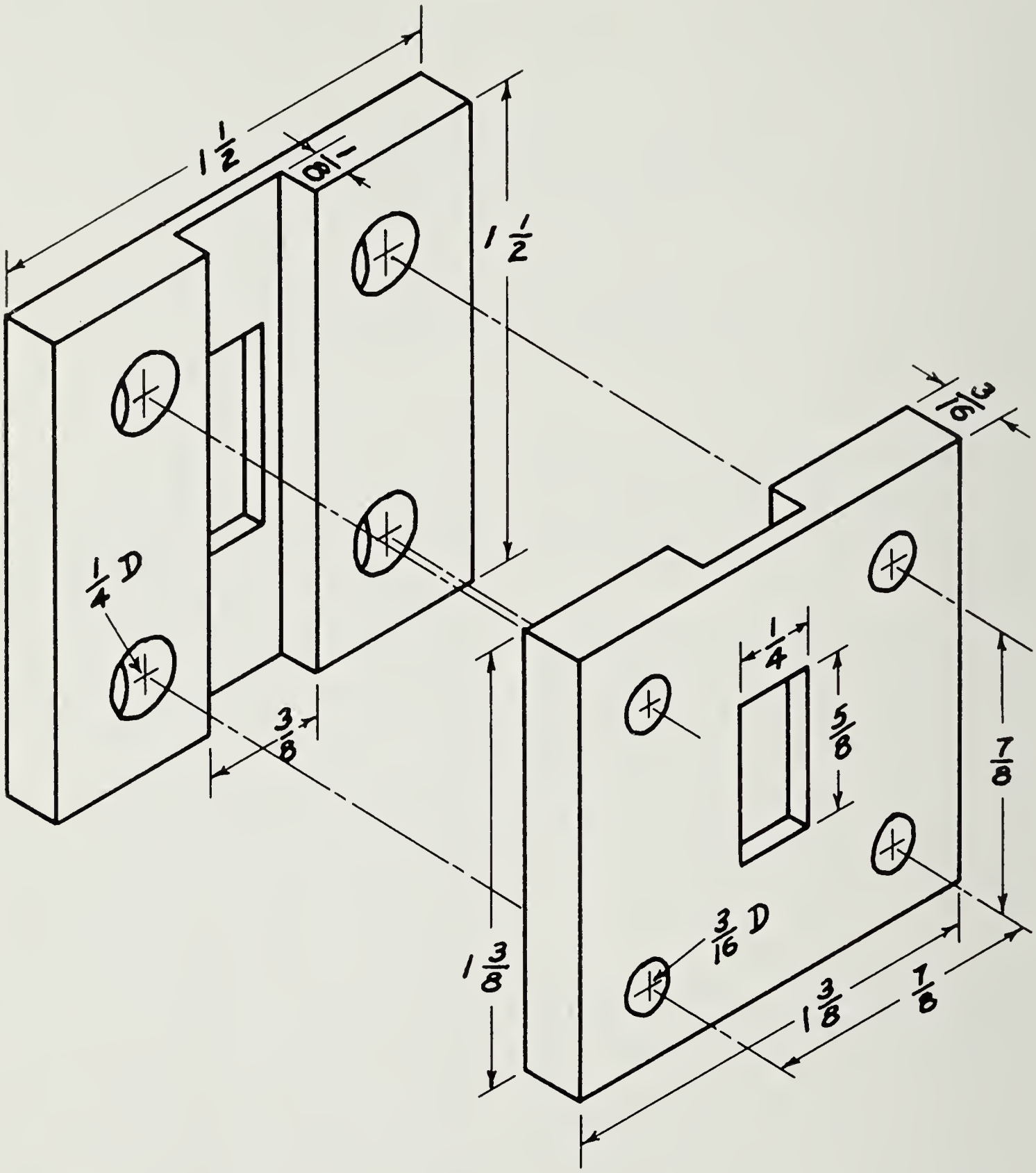

FIGURE 1.—Demountable cell holder adapter for broken sodium chloride windows. Dimensions shown in inches; holes are appropriately centered.

PATTERNS OF CELL DEATH IN ELONGATING CORN STALKS

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ABSTRACT.—The rate of elongation of the 10 internodes above the uppermost brace roots in six inbred lines of corn (B2, B14, C103, R130, 38-11, and Os420) was not related to the pattern of cell death in the internodes. In general, death of cells in the pith tissue occurred in upper internodes earlier than in lower internodes. Death of cells in the lower internodes occurred earlier and in greater numbers in stalk rot susceptible than in stalk rot resistant lines.

Recent studies have indicated that the nature of resistance to spread of *Diplodia zeae* (Schw.) Lev. and *Gibberella zeae* (Schw.) Petch in stalk tissue of corn is related to the death of cells in stalk tissue (Pappelis, 1965; Pappelis and Smith, 1963). All varieties of corn appear to be resistant to naturally occurring stalk rot prior to silking but differ greatly in the time they become susceptible after that time (Koehler, 1960). Michaelson (1957) has indicated that some varieties are susceptible to stalk rot if inoculated prior to silking. Pappelis (1965) recently demonstrated that the death patterns in inbred lines varied greatly and that death of cells in the lower internodes occurred in stalk rot susceptible lines earlier than in resistant lines. The study was conducted after all internodes had elongated. The purpose of the present study was to determine when cells of the lower internodes died, especially in relation to stalk elongation.

Materials and Methods.— Six inbred lines of corn were planted May 21, 1962, in a three-replicate experiment on the Southern Illinois University Agronomy Farm, Carbondale. Plants were grown one foot apart in rows 13 feet long. Each variety subplot consisted of 10 rows with 40 inches between rows. The height measurements of the 10 internodes were made for internodes above the ground in young plants and internodes above the uppermost brace roots in elongated stalks. Internode death patterns were determined by cutting the stalks longitudinally through the central axis and rating the 10 internodes with the following system: 0.0, no dead cells in the internode surface appearing white or fluffy; 0.1, less than 1% of the surface showing dead cells; 0.5, 2-12% dead; 1.0, 13 to 25%; 2.0, 26 to 50%; 3.0, 51 to 75%; 4.0, 76 to 100%; 5.0, as 4.0 with dead cells in the internode linking the areas of dead cells with those in the lower internode; and 6, like 5 with plant dead.

Results and Discussion.— In general, elongation of the 10 internodes in the stalks of all six varieties occurred before late July. The patterns of cell death in the six varieties were similar in that the death of most of the cells occurred in the middle internodes of the stalk, followed by rapid death of cells in the elongating upper internodes. The greatest differences between the six inbreds appeared to be the time when extensive areas of cell death were observed in the first internode.

The cell death patterns for each inbred are presented in Table 1. In B2, dead cells were first observed in the third, fourth, and fifth internodes when only 6 internodes had elongated. The 10 internodes at that time had reached about one-half of the maximum height.

Similarly, dead cells were observed in the stalk of B14, C103, 38-11 after the 10 internodes had elongated to one-half their height. In R130, dead cells were not observed until the 10 internodes had elongated to over one-half the height, while in 0s420, this had occurred as soon as the lower three internodes had elongated to about one-quarter of the height that the 10 internodes would achieve.

With regard to death of cells in the first internode, the most rapid rate of death was noted for 0s420 and the least

TABLE 1.—Pith condition ratings and height of ten internodes of corn inbreds B2, B.14, C103, 38-11, and Os420; 1962, 3 replicates, 5 plants per replicate per sample date.

Date	Internode										Height (inches)
	1	2	3	4	5	6	7	8	9	10	
Inbred B2											
7-6....	0.0	0.0	0.0	0.0	0.0[1]	0.0	0.0	0.0	0.0	0.0	8
7-13...	0.0	0.0	0.3	0.3	0.1	0.0	0.0[1]	0.0	0.0	0.0	20
7-20...	0.0	0.5	2.3	3.0	2.7	2.2	1.3	0.5	0.1	0.0[1]	30
7-27...	0.1	1.1	2.8	3.4	3.4	3.2	2.9	2.4	2.1	1.7	37
8-3....	0.8	1.7	2.9	3.4	3.4	3.4	3.2	3.1	2.9	2.5	37
8-10...	0.6	1.6	3.3	3.9	4.0	4.0	3.9	3.7	3.4	3.3	38
8-17...	1.1	2.9	3.5	3.8	3.9	3.9	3.8	3.7	3.6	3.6	.....
8-23...	0.7	2.0	3.1	3.9	4.0	4.0	4.0	4.0	4.0	4.0	.....
8-30...	1.5	2.9	3.8	4.0	4.0	4.0	4.0	4.0	4.0	4.0	.....
9-6....	1.1	2.3	3.5	3.9	4.0	4.0	4.0	4.0	4.0	4.0	.....
Inbred B14											
7-6....	0.0	0.0	0.0	0.0[1]	0.0	0.0	0.0	0.0	0.0	0.0	9
7-13...	0.0	0.2	0.1	0.0	0.0	0.0	0.0[1]	0.0	0.0	0.0	20
7-20...	0.0	1.2	2.7	3.5	3.1	2.7	2.0	1.2	0.5[1]	0.2	31
7-27...	0.0	1.3	3.1	3.7	3.8	3.7	3.5	3.4	3.0	2.5	38
8-3....	0.0	1.7	3.3	3.8	4.0	4.0	4.0	4.0	3.9	3.8	37
8-10...	0.1	1.6	3.4	3.9	4.0	4.0	4.0	4.0	4.0	4.0	38
8-17...	2.2	3.7	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	.....
8-23...	1.9	3.3	3.9	4.0	4.0	4.0	4.0	4.0	4.0	4.0	.....
8-30...	3.0	3.6	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	.....
9-6....	2.1	3.4	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	.....
Inbred C103											
7-6....	0.0	0.0	0.0	0.0[1]	0.0	0.0	0.0	0.0	0.0	0.0	12
7-13...	0.0	0.0	0.1	0.3	0.0	0.0[1]	0.0	0.0	0.0	0.0	24
7-20...	0.0	0.4	1.8	3.0	2.9	2.3	1.3	0.7	0.1	0.0[1]	37
7-27...	0.3	1.5	2.2	3.3	3.2	3.4	3.4	3.0	2.3	1.9	44
8-3....	0.0	0.3	1.8	3.3	3.6	3.8	3.9	3.7	3.6	2.9	46
8-10...	0.2	1.3	2.3	3.2	3.6	3.9	4.0	4.0	4.0	4.0	47
8-17...	1.3	2.0	2.7	3.4	3.8	4.0	4.0	4.0	4.0	4.0	.....
8-23...	2.2	3.2	3.7	3.9	4.0	4.0	4.0	4.0	4.0	4.0	.....
8-30...	3.6	3.9	4.0	4.0	4.1	4.1	4.2	4.2	4.3	4.3	.....
9-6....	3.6	4.0	4.2	4.2	4.2	4.2	4.3	4.3	4.3	4.3	.....

[1] This and the upper internodes not elongated more than 1 inch.

TABLE 1.—Continued.

Date	Internode										Height (inches)
	1	2	3	4	5	6	7	8	9	10	
Inbred R130											
7-6....	0.0	0.0	0.0	0.0	0.0[1]	0.0	0.0	0.0	0.0	0.0	11
7-13...	0.0	0.0	0.0	0.0	0.0	0.0	0.0[1]	0.0	0.0	0.0	25
7-20...	0.0	0.0	0.4	0.5	0.4	0.1	0.0	0.0	0.0	0.0[1]	40
7-27...	0.0	0.5	1.9	2.5	2.4	2.1	1.6	1.0	0.7	0.5	45
8-3....	0.0	0.5	2.1	2.6	2.6	2.6	2.7	2.3	2.0	1.7	51
8-10...	0.3	1.1	2.3	3.0	3.0	2.9	2.7	2.5	2.3	2.2	48
8-17...	0.6	2.0	2.7	3.2	3.5	3.6	3.6	3.6	3.6	3.7	.....
8-23...	0.6	2.3	3.3	3.5	3.6	3.7	3.7	3.7	3.7	3.7	.....
8-30...	2.0	2.7	3.0	3.1	3.4	3.4	3.3	3.3	3.4	3.4	.....
9-6....	2.2	2.8	3.4	3.6	3.6	3.5	3.6	3.7	3.8	3.8	.....
Inbred 38-11											
7-6....	0.0	0.0	0.0	0.0[1]	0.0	0.0	0.0	0.0	0.0	0.0	12
7-13...	0.0	0.6	0.7	0.1	0.0[1]	0.0	0.0	0.0	0.0	0.0	19
7-20...	1.7	2.9	3.5	3.5	2.9	1.6	0.4	0.0	0.0[1]	0.0	32
7-27...	1.8	3.0	3.6	3.6	3.5	3.1	2.4	1.7	1.0	0.7	39
8-3....	2.3	3.4	3.9	4.0	4.0	4.0	3.8	3.5	3.0	2.8	42
8-10...	2.7	3.5	3.9	4.0	4.0	4.0	4.0	4.0	4.0	4.0	41
8-17...	3.1	3.8	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	.....
8-23...	3.7	3.9	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	.....
8-30...	4.0	4.1	4.1	4.0	4.0	4.0	4.0	4.0	4.1	4.1	.....
9-6....	4.0	4.0	4.1	4.0	4.0	4.0	4.0	4.0	4.0	4.0	.....
Inbred Os420											
7-6....	0.1	0.3	0.2	0.0[1]	0.0	0.0	0.0	0.0	0.0	0.0	11
7-13...	1.7	3.0	2.3	1.2	0.4	0.1[1]	0.0	0.0	0.0	0.0	21
7-20...	2.3	3.6	3.8	3.9	3.7	3.2	2.7	1.9	1.1	0.8	39
7-27...	2.9	3.8	3.9	4.0	4.0	4.0	3.7	3.5	3.4	2.5	48
8-3....	2.7	3.8	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	44
8-10...	3.3	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	45
8-17...	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	.....
8-23...	3.9	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	.....
8-30...	4.6	4.6	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	.....
9-6....	4.7	4.7	4.5	4.4	4.4	4.5	4.5	4.6	4.7	4.7	.....

rapid for B2. On 3 August, the varieties could be grouped according to the amounts of dead cells in the first internode as follows: R130, B14, and C103 rating 0.0; B2 rating 0.8; and 38-11 and 0s420 rating about 2.5. On 23 August the grouping would be: R130 and B2 lowest with ratings about 0.5; B14 and C103 rating about 2.0; and 38-11 and 0s420 rating about 3.8. On 6 September, the varieties would be grouped as follows: B2 lowest with a rating of 1.1; B14 and R130 rating about 2.1; C103 and 38-11 rating about 3.8; and 0s420 rating 4.7.

The internodes in which cell death in the pith tissue apparently occurred first differed in the varieties: in the first through third internodes in 0s420; second and third in 38-11 and B14; third and fourth in C103; third through fifth in B2; and third through sixth in R130. When fully elongated and ears formed, there was no relationship between cell death patterns in internodes and the location of the ears (0s420, two ears generally at internodes 5 and 6; B2 and B14, one ear generally at 6; C103, one ear generally at 7; 38-11, two ears generally at 7 and 8; and R130, one ear generally at 8). The fastest rate of cell death indicated by the change in rating in all varieties appeared in the fourth through sixth internodes after mid-July. The pattern of cell death in pith tissue of the nodes did not occur in a similar pattern in the three lines in which this was observed; 38-11, C103, and 0s420.

The trait of cell death in pith tissue appears to be uniform in the plants of each inbred and confirms the earlier work of Pappelis (1965) indicating wide differences in the patterns in susceptible and resistant inbreds. From these studies, it now appears likely that cell death patterns may prove helpful in detecting stalk rot susceptibility at a very early stage of stalk development. This should be helpful in genetic studies on the nature of stalk rot resistance in which the characteristic patterns of cell death in inbreds can be studied in various genetic combinations.

Acknowledgments

This study was supported in part by Bear Hybrid Corn Company, Decatur, and the Producers Seed Company, Piper City, Illinois. The authors wish to thank Dr. A. L. Hooker, University of Illinois, Urbana, for providing the seed used in this study.

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Manuscript received February 12, 1966.

ADDITIONS TO THE VASCULAR FLORA OF CARROLL COUNTY, ILLINOIS

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ABSTRACT.—An examination of two unmounted collections of vascular plants from Carroll County, Illinois has yielded 26 new species not previously recorded for the area. This increases the total known vascular flora of Carroll County to 729 species.

The total reported vascular flora of Carroll County, Illinois, consisted of 505 species, according to the data compiled by Jones and Fuller (1955) and Winterringer and Evers (1960), until a study of the Mississippi Palisades State Park was conducted by the author (Wunderlin, 1966).

This study revealed 198 county records, increasing the total known vascular flora to 703 species. After recently examining two unmounted collections, one made by B. J. Verts in August, 1963, and one made by the author in June, 1962, the author discovered 26 unreported species. This increases the total known vascular flora of Carroll County to 729 species. This number is, in the author's opinion, considerably less than what actually occurs there. It is the author's intention to continue collecting in Carroll County to determine more exactly the actual vascular floral composition of the area.

The following list constitutes the 26 species of vascular plants not previously recorded for Carroll County that have been recently discovered by the author. Each species is followed by the collector's name and number. All specimens are deposited in the herbarium at Southern Illinois University, Carbondale.

The order of plant families and the nomenclature is that of Jones (1963).

Berberidaceae Torr. & Gray

Berberis thunbergii DC. Verts 332.

Papaveraceae B. Juss.

Chelidonium majus L. Verts 188

Cruciferae B. Juss.

Nasturtium officinale R. Br. Verts 93.

Malvaceae Necker

Hibiscus trionum L. Verts 81.

Aizoaceae A. Br.

Mollugo verticillata L. Wunderlin 322.

Zygophyllaceae Lindl.

Tribulus terrestris L. Wunderlin 316.

Euphorbiaceae J. St. Hil.

Euphorbia cyparissias L. Verts 234.

Rosaceae Juss.

Agrimonia parviflora Ait. Wunderlin 261.

Leguminosae P. F. Gmel.

Desmodium canescens (L.) DC. Verts 124.

Robinia pseudoacacia L. Wunderlin 302.

Moraceae Lindl.

Maclura pomifera (Raf.) Schneid. Verts 26.

Onagraceae Dumort.

Oenothera strigosa (Rydb.) Mack. & Bush, Wunderlin 308.

Primulaceae Vent.

Lysimachia lanceolata Walt. Wunderlin 262.

Solanaceae Pers.

Solanum rostratum Dunal, Verts 104.

Scrophulariaceae Lindl.

Verbascum blattaria L. Verts 318.

Bignoniaceae Pers.

Catalpa bignonioides Walt. Verts 304.

Compositae P. F. Gmel.

Cirsium arvense (L.) Scop. Verts 87.

Galinsoga ciliata (Raf.) Blake, Verts 115.

Cyperaceae J. St. Hil.

Cyperus filiculmis Vahl. Verts 162.

Cyperus ferruginescens Boeck. Verts 130.

Cyperus schweinitzii Torr. Wunderlin 350.

Gramineae Juss.

Avena sativa L. Verts 42.

Bromus japonicus Thunb. Verts 206.

Bromus kalmii A. Gray, Verts 218.

Miscanthus sacchariflorus (Maxim.) Hack. Verts 294.

Setaria faberi Herrm. Verts 10.

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Manuscript received February 9, 1966.

NUTRIENT CONTENT AS RELATED TO SENESCENCE IN SUGAR CANE

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ABSTRACT. — Fifteen successive internodes of two varieties of sugar cane (C.P. 52-68, red rot resistant; and Co. 290, red rot susceptible) have been analyzed for potassium and phosphorus contents. In the case of potassium contents, computed on the basis of volume of tissue (i.e. on a "per cc" basis), trends are in a downward direction as one goes up the plant; in the case of phosphorus, computed the same way, the rot resistant variety shows a definite downward trend whereas the rot susceptible variety shows only a slight downward trend.

Preliminary studies on the physiology of senescence and parasitism in sugar cane recently have been reported (Pappelis and Katsanos, 1965a). These investigators have applied to this crop investigational techniques already employed in studies of a similar nature in field corn and in sorghum. In general, they have found that since both fresh and dry weights of tissue vary on a per unit volume basis the most significant correlations are found between physiological condition and the "per cc" or volume basis rather than as percentages of fresh or dry weight. Dead cell areas were correlated with susceptibility to the red rot pathogen (Pappelis and Katsanos, 1965b).

That nutrient status relates to senescence and to susceptibility to rotting pathogens has been reported before. It has been suggested (Kohler, 1960) that among other conditions associated with susceptibility of field corn to stalk rot was potassium supply as related to supply of nitrogen, and also to general fertility levels. In particular, as nitrogen levels rose, low potassium levels were related to susceptibility. High fertility levels generally were associated with stalk rot susceptibility too.

In studies of nutrient levels in culture solutions as related to Gibberella rot of field corn (Thayer and Williams, 1960) it has been shown that, with increased phosphorus level, development of rotting was reduced. In addition, it was observed that nitrogen and potassium were related in their influences on rotting susceptibility. At medium and high potassium levels increasing nitrogen increased stalk rot but at low potassium levels this situation did not obtain. At low nitrogen levels an increase in potassium levels induced decreased rotting; at medium nitrogen levels it had no effect; at high nitrogen levels it increased rotting.

In the present work potassium and phosphorus contents in sugar cane tissue were determined in an effort to uncover a connection between nutrient content and physiological association with senescence and parasitism.

MATERIALS AND METHODS

Sugar cane (*Saccharum officinarum* L.) varieties 'C.P. 52-68' (red rot resistant) and 'Co. 290' (red rot susceptible) were planted in ground beds in a greenhouse at Murphysboro, Illinois on 21 February 1963. Four stalks of each variety were collected on 25 November 1963 by cutting below the uppermost adventitious roots. At this time all cell elongation in the internodes had ceased. Fifteen internodes above the uppermost brace roots were separated for sampling by being cut through the node. The ends of the internodes then were cut off and parenchyma samples were obtained from each internode by passing a cork borer longitudinally through the internode piece. The resulting cylinders were measured for length, weighed for fresh weight, and after being dried at 70°C for 48 hours

were weighed for dry weight. The pith condition ratings (based on number of dead cells in the internode) of each piece had been determined in work reported earlier (Pappelis and Katsanos, 1965a).

Each dried parenchyma cylinder then was digested individually in a nitric-sulfuric-perchloric acid mixture and the phosphorus and potassium contents of each piece were determined. Phosphorus was measured by a stannous-chloride-reduced molybdenum blue method (Jackson, 1958, p. 141); potassium with a Coleman Jr. Flame photometer.

The results were submitted together with original fresh weight, dry weight, pith condition rating, and cylinder dimension data to an IBM 1620 computer for calculation of volume of pieces, fresh weight/cc, dry weight/cc, potassium/cc, phosphorus/cc, percent potassium on a dry weight basis, and percent phosphorus on a dry weight basis. Then these values all were intercorrelated to detect any significant relationships.

Experimental Results

The results of the nutrient content determinations are presented in Figures 1 and 2 in which the independent variable always is internode number beginning with the first internode above the uppermost brace roots. In each figure the upper part presents mg potassium or μg phosphorus per g dry weight of internode parenchyma. The lower part presents mg potassium or μg phosphorus per cc of internode parenchyma. Each point in these figures is the average of four separate determinations.

The results presented in Figure 1 are for C.P. 52-68, the red rot resistant variety; those in Figure 2 are for Co. 290, the red rot susceptible variety.

Discussion

Examination of Figure 1 will reveal the differences which are obtained when two interpretational methods are employed. In the upper part of Figure 1 (which is for C.P. 52-68, the resistant variety), element content on the basis of dry weight shows no physiologically significant changes in relation to internode number. The general upswing in phosphorus content in the higher internodes is in contrast with that reported by other investigators (van Dillewijn, 1952, p. 176). Note, however, that on a "per cc" basis, physiologically significant differences exist between internodes. A generally downward trend is observed for the content of both elements when the volume basis is employed. These differences in interpretation are related to the fact that while the volume of tissue remains constant, the dry matter/cc decreases from about 200 mg in the first internode to about 50 mg in the fifteenth internode. As a result of this, a 400% error is possible in reporting 1% content on a dry matter basis for each internode. As in corn (Abney, 1964; Betterton, 1963; Pappelis, 1957), both fresh weight and dry weight per cc of internode tissue vary and it is suggested that the percent of dry weight is not as reliable a point of reference as is the volume basis. It would seem that the volume basis is physiologically more meaningful in stud-

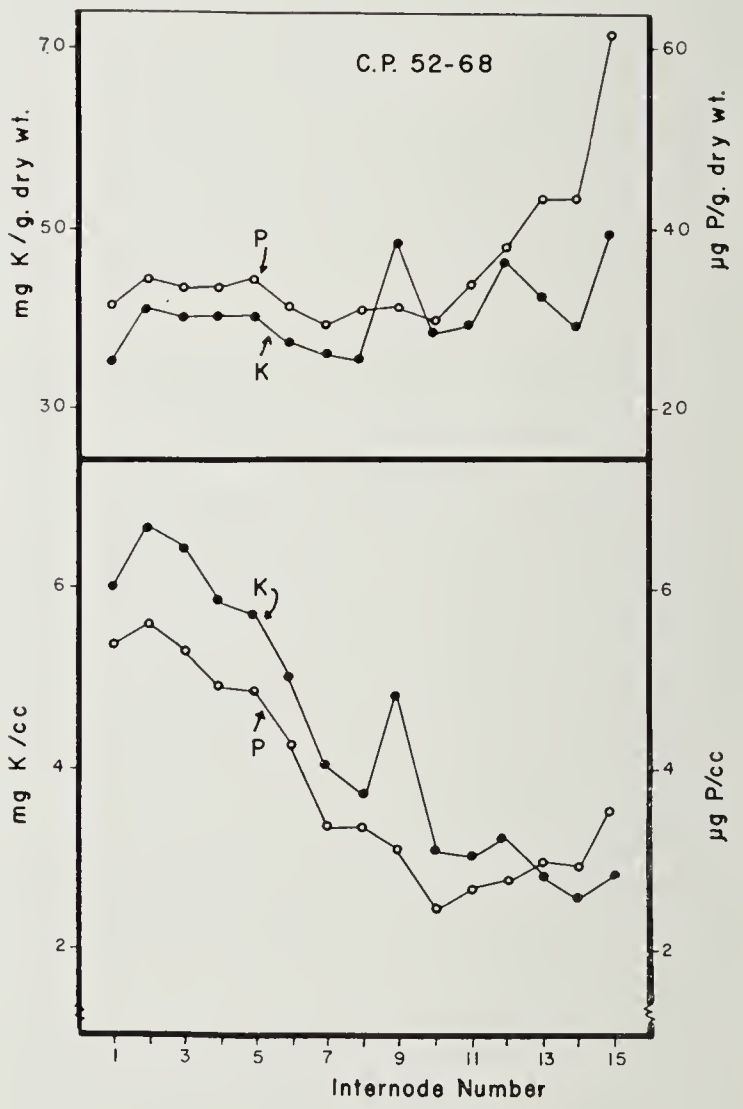

Figure 1.—Potassium and phosphorus contents of sugar cane variety C.P. 52-68 internodes as a function of internode number. Horizontal axis gives internode number beginning with first internode above the uppermost brace roots. Upper curves: mg K/g. dry wt. (closed circles); μg P/g. dry wt. (open circles). Lower curves: mg K/cc of tissue (closed circles); μg P/cc of tissue (open circles).

ies of tissues with elongated cells and that the trends shown in the lower part of Figure 1 are more important than are the absolute amounts involved.

In Figure 2 results for the red rot susceptible variety are presented. Here, too, the percent of dry-weight-based values remain essentially level (upper part of figure) and no upswing is noted in nutrient content in the higher internodes. Comparison of the lower part of Figure 2 with the lower part of Figure 1, however, reveals some difference. The line representing phosphorus content in μg/cc shows a smaller slope in Figure 2 than it does in Figure 1. Thayer and Williams (1960) reported that with increased phosphorus levels in the nutrient solutions, rotting in field corn was reduced. It is suggested that perhaps the difference in phosphorus-content trends on the "per cc" basis also may associate with susceptibility in sugar cane.

From the correlations which were done, it was observed that dry weight /cc is more closely related to phosphorus/cc ($r = 0.878$) than it is to potassium/cc ($r = 0.618$) and that the pith condition rating based on areas of dead cells is very negatively correlated to fresh weight/cc (density) ($r = -0.783$). In the latter case higher tissue density is concomitant with more living cells and this means that the pith condition rating will be lower.

It is of interest to note that phosphorus content on a μg/cc basis does not correlate well with pith condition rating ($r = -0.395$), for while phosphorus content on this basis shows slow downward trends with higher internodes the pith condition rating is minimal in the basal internodes and in the upper internodes (few or no dead cells) but reaches a maximum (greatest number of dead cells) in the middle internodes.

It is suggested on the basis of these results that future studies on relationships between nutrient element content of plant tissues and susceptibility to pathogens be based on the volume or per cell basis, not the dry weight basis. Furthermore, while it appears possible that tissue phosphorus levels on the volume basis, in the lower internodes, may be significantly related to rot susceptibility, probably through association with some metabolic, anti-fungal constituent found in living cells, no such relationship can be easily supported when 15 of the internodes are studied. Since cell death rates are higher in the middle internodes, no relationship appears to exist between the phosphorus or potassium content and rate of cell death in sugar cane stalk tissue. Whether the rate of loss of these elements from the internode cells is correlated with the rate of cell death is not known since this type of study requires more than one sampling date.

ACKNOWLEDGMENTS

This study was supported in part by a grant from the National Science Foundation (GB-1072).

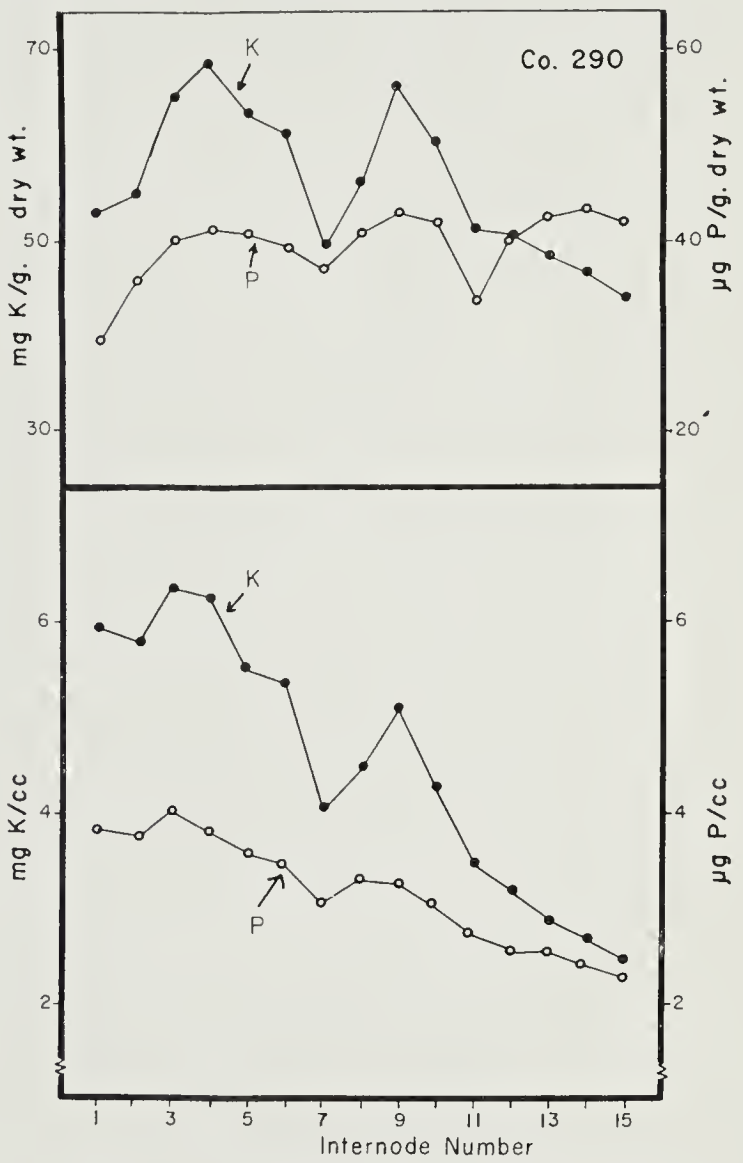

FIGURE 2.—Potassium and phosphorus contents of sugar cane variety Co. 290 internodes as a function of internode number. Horizontal axis gives internode number beginning with first internode above the uppermost brace roots. Upper curves: mg K/g. dry wt. (closed circles); μg P/g. dry wt. (open circles). Lower curves: mg K/cc of tissue (closed circles); μg P/cc of tissue (open circles).

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Manuscript received February 12, 1966.

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Transactions

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Illinois State Academy of Science

Volume 59
No. 3
1966

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Springfield, Illinois

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TRANSACTIONS

OF THE

ILLINOIS STATE ACADEMY OF SCIENCE

VOLUME 59 - 1966 No. 3

Illinois State Academy of Science

affiliated with the

Illinois State Museum Division

Springfield, Illinois

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

Otto Kerner, *Governor*

September 1, 1966

CONTENTS

Petrographic and Modal Analysis of the Andesite of Marble Creek, Southeastern Missouri.
By Ira R. Satterfield 207
A Record of *Democricetodon* (Order Rodentia) from the Late Tertiary of Northeastern Colorado.
By Edwin C. Galbreath 212
Some Pleistocene Turtles from Illinois.
By J. Alan Holman 214
Application of the Tyndall Effect to the Evaluation of the Solubility Product for Aluminum Tris-(8-Hydroxyquinolate).
By R. E. Van Atta, R. S. Cichorz and Han-Lin Hwang Chen .. 217
Analyses of the Effects of Four Components in Cigarettes on *Paramecium aurelia*.
By H. Wang 222
Nativistic Movements and Modern Nationalism.
By Konstantin Symmons-Symonolewicz 236
Midwestern Dendrochronology and Archaeological Dating.
By Patrick J. Munson 241
Avoidance of Staining Artifacts in Smears of Ectotherm Blood.
By Harold M. Kaplan and Sheila S. Glaczenski 246
Hydrolysis of Adenosinetriphosphate by Bluegill Liver Mitochondria.
By Robert C. Hiltibran 249
The Genus *Peniophora* in Illinois.
By Robert J. Harris 254
Akinetes, Reproduction, and Colony Form in the Green Alga *Sorastrum*.
By Joseph S. Davis 275
Burgner Acres Natural Area of Eastern Illinois University.
By Steve Henderson and Kenneth E. Damann 281
News and Comments 287
Polyeders of *Pediastrum simplex*.
By Joseph S. Davis 289
Notes on *Eupatorium* (Compositae) in Illinois.
By R. P. Wunderlin 290
A Microorganism Found in the Latex of *Euphorbia marginata* Pursh. (Euphorbiaceae).
By Ralph Troll 292
Spiders of Illinois: Additional Species.
By Bennett C. Moulder 294
Notes on a Collection of Amphibians and Reptiles From Monroe County, Illinois.
By Ronald A. Brandon and Nathan R. Austin 296
Kill of Mammals and Birds and Entrapment of Turtles on Railroad Tracks.
By Don R. Helms and Howard J. Stains 297
Herpetological Records from Northcentral Illinois.
By J. Alan Holman 298

PETROGRAPHIC AND MODAL ANALYSIS OF THE ANDESITE OF MARBLE CREEK, SOUTHEASTERN MISSOURI

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Southern Illinois University, Carbondale

Abstract. — A detailed field and petrographic investigation was made of the andesite of Marble Creek in the St. Francois Mountains of southeastern Missouri. The area is characterized by hills of Precambrian granitic and felsitic rocks which rise topographically above unconformably overlying Cambrian strata. The andesite has a porphyritic texture, contains an abnormally high percentage of plagioclase, and quartz, and only minor amounts of biotite, hornblende, and augite. Petrographic and field studies lead the author to believe that the andesite was a flow.

Geology and Stratigraphy

The St. Francois Mountains, made up in part by the andesite of Marble Creek, form part of the Ozark Dome. The Dome is a broad, nearly circular, area of Cambrian and Ordovician limestones and dolomites surrounded by excarpments of Mississippian limestones. In the east central part of the St. Francois Mountains, knobs of Precambrian igenous rocks are exposed through the Cambrian and Ordovician strata. According to Hayes (1961) the erosional surface on the Precambrian rocks had considerable relief before the Cambrian seas transgressed the area. The Cambrian strata dip off the Precambrian at approximately 5 to 15 degrees but this in no way indicates the relief of the erosional surface before Cambrian times inasmuch as the area was uplifted contemporaneously with deposition.

In areas adjacent to the study area, the Precambrian rocks consist of a series of rhyolites and felsitic rocks intruded by granitic stocks and sills. Basic dikes and sills have intruded both felsitic rocks and granites. The largest mass of rhyolite, the Stouts Creek Rhyolite, occurs at the northern boundary of the study area. No contact between the rhyolite and the andesite was observed. The Stouts Creek Rhyolite and the andesite of Marble Creek are older than the intruding granites which, according to Allen (1959), range from 1200 m.y. to 1350 m.y. in age.

The andesite of Marble Creek is to be found between the towns of Arcadia and French Mills (Fig. 1). The andesite crops out along County Route E at two localities which jointly cover an area of approximately one-half square mile. The western area is located in the SW¼ Sec. 24, T.32N., R.4E. in Iron County and the eastern body is in the NW¼ Sec. 19, T32N., R.5E. in Madison County. Both areas are entirely within the Des Arc 15-minute Quadrangle, thus lying between me-

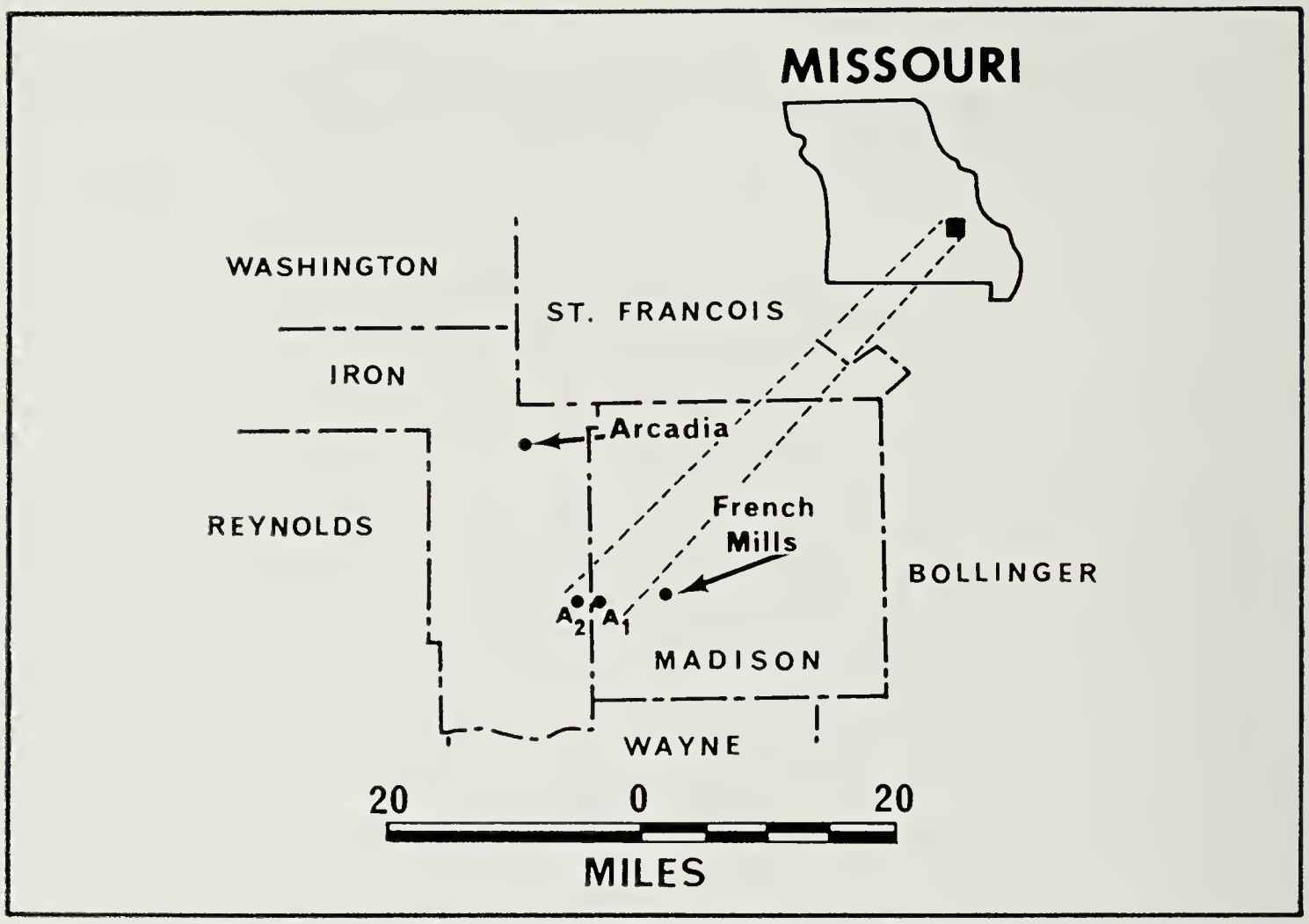

FIGURE 1. — Map showing location of andesite of Marble Creek in southeastern Missouri.

ridians 90°30′ and 90°45′ west longitude and parallels 37°15′ and 37°30′ north latitude.

Only one sedimentary formation, the Bonneterre Dolomite (Upper Cambrian), is exposed in the study area. The oldest sedimentary unit of Paleozoic age in the region, the Lamotte Sandstone, probably was not deposited locally. The dolomite is characteristically buff in color, coarsely crystalline, and produces a brownish-red soil. Strata of the Bonneterre surround all of the west andesite body A_2 and approximately two-thirds of the east body A_1 (FIG. 2). The exposed igneous rock weathers to a dark-colored, pitted surface.

PETROGRAPHY

Megascopic Description.—The andesite of Marble Creek is black, slightly vesicular, and generally prophyritic. Its most striking characteristics are that most of the euhedral plagioclase phenocrysts have been slightly epidotized and that the andesite weathers to give a deep reddish-brown soil. Plagioclase phenocrysts range from 1mm to 6mm in length and constitute approximately 20 to 25 percent of the rock. There appears to be a slight linear orientation of the plagioclase phenocrysts but there is no apparent geometric orientation of the vesicles. The vesicles range from less than 1mm to 6mm in length.

Thin Section Analysis.—In body A_1 the rock is composed of plagioclase, quartz and hornblende, magnetite, and accessory minerals (TABLE 1). Andesine feldspar comprises approximately 70.5 percent of the slides and occurs as euhedral phenocrysts, which range from 2mm to 6mm in length and make up about one-third of the total plagioclase. Such phenocrysts tend to exhibit linear flow structure. Some of the phenocrysts show normal zoning and many are highly fractured, but such fractures do not extend into the groundmass. All of the plagioclase crystals in the mesostasis along the plagioclase phenocrysts tend to parallel the phenocrysts. Magnetite tends to be disseminated equally

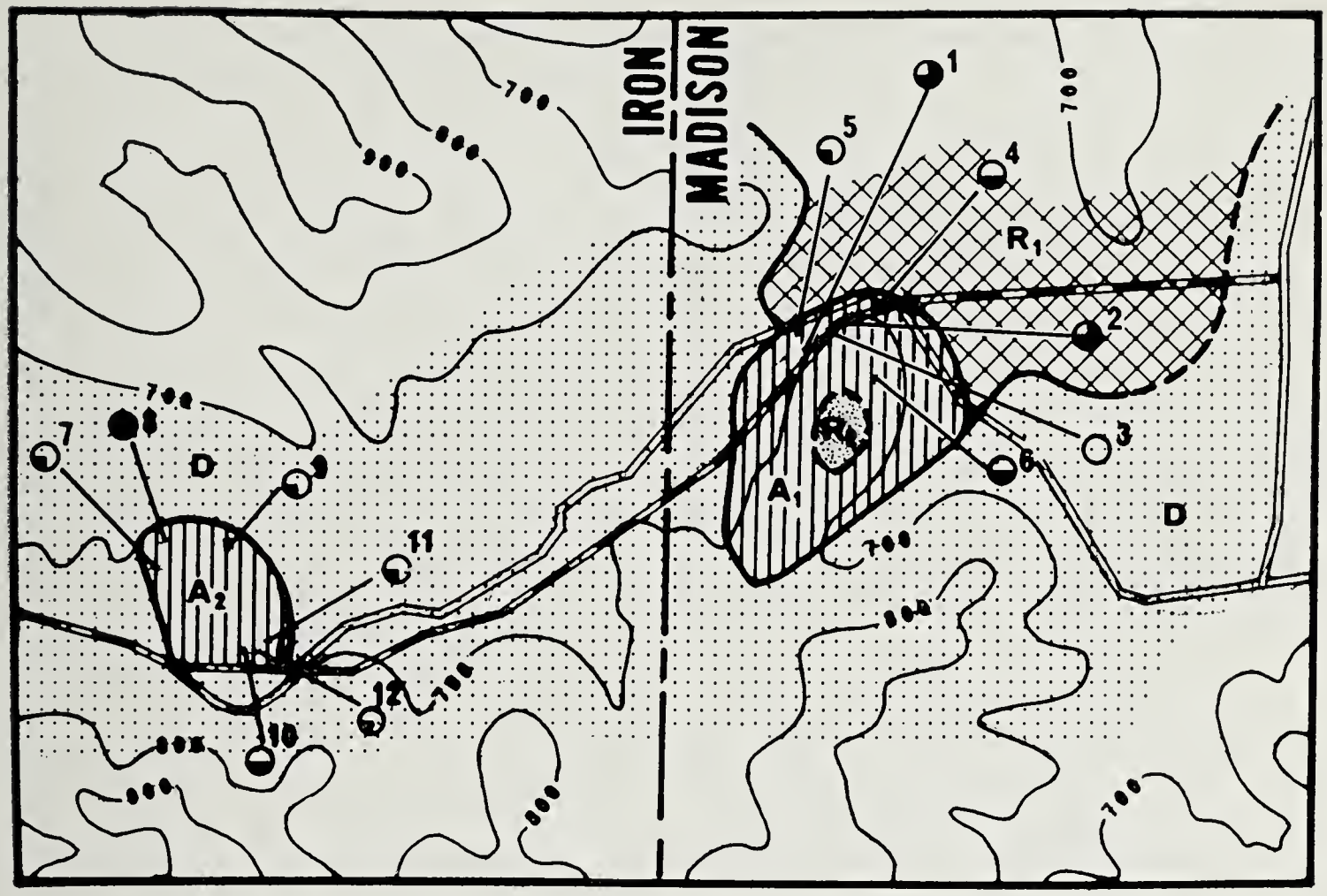

FIGURE 2. — Geologic map of the area showing locations of the samples and approximate percent of plagioclase feldspar. Sample numbers correspond with Modal Analysis in Table I.

throughout the rock. A few crystals are up to 3mm in length. Several of the slides have thin (1mm) quartz veins which contain a small amount of sericite. The quartz is confined to veins, to groundmass, and to vesicular filling. All of the augite, hornblende, and most of the plagioclase show deuteric alteration and replacement.

In body A_2 the rock is composed of plagioclase, quartz, calcite, magnetite, augite and hornblende, and accessory minerals (TABLE 1). Plagioclase feldspar comprises approximately 70.6 percent of the slides but their original composition is uncertain due to dueteric alteration. Such phenocrysts comprise about 8 to 10 percent of the total composition and differ in length from those in the eastern body—ranging 1mm to 3mm. The plagioclase phenocrysts have a parallel linear orientation suggestion flow and exhibit tensional fractures which do not extend into the groundmass. The plagioclase crystals in the mesostasis immediately adjacent to the plagioclase phenocrysts tend to parallel the border of the phenocrysts. Mag-

TABLE 1.—Modes of the Andesite of Marble Creek, Missouri (In Percent)

Body A_1

Location and Number	1	2	3	4	5	6
Plagioclase[1]	28.2	15.9	21.9	21.2	24.4	0.3
Quartz	.....	6.7	3.2	.....	.....	1.2
Magnetite	5.5	3.4	2.0	2.6	11.0	1.1
Calcite	.....	.....	.....	.....	.....	.....
Accessory[2]	4.1	1.5	35.4	11.5	3.6	1.3
Groundmass	62.2	72.5	37.5	64.7	61.0	96.1
(a) Plagioclase	76.3	82.3	94.4	79.1	72.8	76.4
(b) Quartz	14.2	15.4	.....	12.9	.....	8.0
(c) Magnetite	9.5	2.2	5.6	8.0	27.2	15.6
Total Plagioclase	75.6	75.5	57.0	72.4	68.8	73.7

Body A_2

Location and Number	7	8	9	10	11	12
Plagioclase[1]	6.3	2.9	5.3	6.5	4.5	0.5
Quartz	1.5	4.6	.....	4.7	0.2	.....
Magnetite	0.3	0.2	0.8	0.4	1.1	0.6
Calcite	2.8	.....	4.0	3.2	0.2	.....
Accessory[2]	9.3	0.4	4.9	2.3	2.5	.....
Groundmass	79.8	91.9	85.0	82.9	91.5	98.9
(a) Plagioclase	84.4	84.7	75.0	77.1	70.5	65.7
(b) Quartz	.....	12.0	9.4	8.9	14.0	10.8
(c) Magnetite	15.6	3.3	15.5	14.0	15.5	23.5
Total Plagioclase	69.1	80.7	69.0	70.4	69.0	65.4

[1] Andesine phenocrysts with extinction angles in mid-upper 20's.
[2] This group is composed of augite, hornblende, chlorite and epodite.

netite is disseminated equally throughout the slides with a few crystals up to ½mm in diameter. The rock is considerably more vesicular than those of the eastern body A_1 but the vesticles do not appear to have any geometric orientation. Most of the vesicles have been filled with calcite which in turn has been partially replaced by later calcite and chalcedonic quartz. All of the augite, hornblende, and plagioclase phenocrysts show dueteric alteration and replacement. Most of the slides contain small quartz vein (½mm). The quartz is restricted to the veins, mesostasis, and vesicles.

DISCUSSION

The plagioclase phenocrysts were the first to crystallize out of solution. This is exhibited by the euhedral crystal form, the tensional fractures in the plagioclase, and that the plagioclase crystals in the mesostasis tend to be parallel with the plagioclase phenocrysts. No biotite, and only a small amount of hornblende, was encountered in any of the thin sections examined.

The high percentage of plagioclase might be explained if the crystallizing magma rose to the surface slowly.

Much of the quartz was added later after the bodies solidified as evidenced by the quartz veins and quartz replacing calcite in the vesicles.

No contacts were observed in the field mapping; hence, the author did not observe any strongly affirmative criteria which would distinguish the bodies as a flow or a sill. A flow origin is favored because: (a) the underlying Stouts Creek Rhyolite is a flow (Hayes, 1961), (b) flow structure was observed in the field and in the thin sections, (c) the overlying rhyolite is probably a flow, (d) the tensional fractures in the plagioclase phenocrysts, and (e) the plagioclase crystals in the mesostasis tend to parallel in orientation the immediately adjacent plagioclase pheocrysts.

Due to the abnormally high percentage of plagioclase, the andesite should be called 'feldspathic andesite'.

Acknowledgments

The writer wishes to thank the Geology Department of Southern Illinois University for the use of the equipment and facilities. He also wishes to extend thanks to Dr. Dewey H. Amos for his assistance in the field and during the preparation of the manuscript.

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Manuscript received December 29, 1965.

A RECORD OF *DEMOCRICETODON* (ORDER RODENTIA) FROM THE LATE TERTIARY OF NORTHEASTERN COLORADO

EDWIN C. GALBREATH
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ABSTRACT. — *Democricetodon* (D.) sp. is reported from latest Miocene or earliest Pliocene deposits in Weld County, Colorado.

A damaged rodent jaw and several teeth similar to the teeth of old world cricetids were found in Weld County, Colorado, in deposits judged to be of latest Miocene or earliest Pliocene Age. This material was recovered from a thin and restricted layer of well-weathered volcanic ash. All physical evidence suggests that the deposit represents an accumulation in a pond or a slow, sluggish stream. These specimens were collected in the vicinity of Pawnee Buttes in Weld County, Colorado. Exact locality and stratigraphic data are on file in the University of Colorado Museum at Boulder—the repository for the specimens.

Details pertaining to the material collected, catalogue numbers, and dimensions are recorded in TABLE 1. Parts of at least four individuals are present. Specimens numbered 27391 (RM_1) and 27392 (RM_2) are well worn teeth that could represent parts of one individual. Teeth numbered 27393 and 27396 are illustrated in FIGURE 1.

These teeth have been assigned to the genus *Democricetodon,* subgenus *Democricetodon* Fahlbusch (1964) because of their close resemblance to specimens assigned to this group and because, in most respects, the features of these teeth agree with the diagnostic criteria set forth by Fahlbusch. A useful criterion, but not one regarded to be of taxonomic worth, is the fact that Dr. Fahlbusch examined these specimens on two occasions and agrees to their assignment to the subgenus *Demicricetodon*. The possibility that the teeth could belong to some cricetid with a North American history was reviewed and rejected.

The jaw has the incisor broken off deep to the alveolus, has lost all the molars, and lacks the posterior border and the upper part of the ascending ramus. I think the jaw belongs with the teeth because it has a cricetid-like conformation, is of the size to accommodate the teeth

FIGURE 1. — Occlusal view of LM_2 (Univ. Colorado Mus. No. 27393) and RM^{2-3} (Univ. Colorado Mus. No. 27396) of *Democricetodon* (*D.*) sp. from Weld County, Colorado.

TABLE 1.—Dimensions (in mm) of Specimens of *Democricetodon* (*D.*) sp. from Weld County, Colorado.

Univ. Colorado Mus. Number		Antero-posterior length	Transverse width
27391	RM_1	1.67	1.13
27392	RM_2	1.37	1.22
27393	LM_2	1.39	1.13
27394	LM_2	1.42	1.14
27395	RM_3	1.39	1.03
27396	RM^2	1.37	1.35
	RM^3	0.93	1.03
27397	Right jaw		
	Incisor width at point 2.0 mm deep to the alveolus		0.8
	Incisor depth at point 2.0 mm deep to the alveolus		1.8+
	Alveolar length of molar tooth row		4.5
	Length of diastema, alveolus to alveolus		3.0
	Greatest depth of jaw from septum between roots of first molar to ventral border		3.9

found in the deposit, and does not differ from the fragments of jaw bone associated with specimens numbered 27392 and 27395. A feature of the jaw that merits comment is the presence of an incisor capsule that is small, but well-formed, and prominent enough to be separated from the ramus by a groove. The masseteric fossa has the ventral border marked by a ridge that, anteriorly, curves upward and fades out as a trace below the anterior root of the first molar. The sharp anterior border of the ramus extends to a point even with the anterior root of the second molar. The mental foramen is high on the side of the jaw, being slightly antero-external to the alveolar border. A comparison of this jaw with the figure of a jaw of *Democricetodon* (*D*) *minor gracilis,* seen in Fahlbusch's paper (Taf. 2, figs. 5a and 5b), shows that the Colorado specimen has a shallower masseteric fossa.

The incisor is flat on the medial side and slightly convex on the lateral side.

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Manuscript received March 15, 1966.

SOME PLEISTOCENE TURTLES FROM ILLINOIS

J. ALAN HOLMAN
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ABSTRACT. — Three species of turtles from gravels of the Clear Lake Pleistocene (Wisconsonian) site near Springfield, Sangamon County, Illinois represent forms that occur in the area today.

Techter (1961) summarized the few known fossil turtles of Illinois which are: *Terrapene ornata* (Agassiz), *Pseudemys* sp., and *Chrysemys* (?) sp. Thus, I was pleased to receive for study, through the courtesy of Edward A. Munyer and Paul W. Parmalee of the Illinois State Museum, the remains of turtles from gravels of the Clear Lake Sand and Gravel Company which lies four miles east of Springfield and south of Riverton near the Sangamon River (Sec. 22, T 16 N, R 4 W, Sangamon County, Illinois).

According to the original label the fossils were donated in the early 1940's by Mrs. White who got them from some men who collected the bones from the gravel deposits of Clear Lake. The fossil turtle bones from Clear Lake are well mineralized, and fortunately, some of the elements (FIG. 1) have diagnostic characters. Numbers applied to the fossils are those of the Illinois State Museum, Springfield, Illinois.

Other fossils from this site represent mastodon, mammoth, moose, and a few other mammalian remains of animals that live in the area today (E. A. Munyer, personal communication). These remains indicate that the deposition of these particular gravels at Clear Lake represents a recessional time during the Wisconsonian age of the Pleistocene.

Chelydra serpentina (Linnaeus)

Geologic range.—Hemphillian-Recent.
Material.—Precoracoid-scapula, CL 416105.
Remarks.—The precoracoid-scapula of Recent *Chelydra* may be distinguished from those of all other North American Recent turtle genera in that the precoracoid makes an angle of about 90 degrees with the scapula and in that the distal ends of both bones are deeply striated. I am unable to separate the fossil element from those of Recent *Chelydra serpentina*, a species that lives in a wide variety of aquatic habitats in the area today.

Pseudemys scripta (Schoepff)

Geologic range. — Sangamon - Recent.
Material. — Proneural, two right and three left hyoplastra, one left hypoplastron, CL 416106.
Remarks. — Based on characters discussed in Holman (1963) I have assigned the proneural bone to the species *P. scripta*. The other *Pseudemys* bones are indistinguishable from those of Recent *P. sripta* specimens at hand and thus are also assigned to this species. *Pseudemys scripta*, a form that prefers quiet water with lots of vegetation, has been reported from Springfield, Illinois during Recent times by Cagle (1946).

Trionyx spinifer Le Sueur

Geologic range.—Kansan - Recent.
Material.—Right hyoplastron, left hypoplastron, CL 416105; partial peripheral, CL 416104.

FIGURE 1. — Fossil turtle bones from the Pleistocene (Wisconsonian) of Clear Lake, Sangamon County, Illinois. Numbers are those of the Illinois State Museum, Springfield, Illinois. From left to right: CL 416105 procoracoid-scapula of *Chelydra serpentina*, CL 416106 proneural of *Pseudemys scripta*, CL 416104 hyoplastron of *Trionyx spinifer*.

Remarks.—The fine sculpturing of the shell bones of the genus *Trionyx* immediately distinguishes it from other genera of North American turtles. Webb (1962) points out that the unit formed by the articulated hyoplastron and hypoplastron is shorter and wider in *Trionyx muticus* Le Sueur than in *T. spinifer* and *T. ferox* (Schneider). This condition is reflected in the shape of the hyoplastron bone. Based on two Recent specimens of *T. muticus* and six of Recent *T. spinifer* at hand, the hyoplastron is shorter and wider in the former species than in the latter. The fossil is similar to *T. spinifer* in this character, and since *T. ferox* is presently restricted to Florida, Georgia, and South Carolina (Conant, 1958, map 34), I have assigned the fossil hyoplastron to the species *T. spinifer*. I have assigned the other *Trionyx* fossils to *T. spinifer* although I am unable to find specific diagnostic characters on these bones.

Although undocumented by records, *T. spinifer* apparently occurs in the area today (Smith, 1961, fig. 140). The other Illinois species of softshell turtle, *T. muticus*, occurs in the Illinois River to the west of Springfield, but it is questionable that it occurs at Springfield (Smith, op. cit., fig. 138). Smith states that "*T. s. spinifer* has a much greater ecological tolerance in Illinois than *T. muticus*, as it can be found in lakes, sloughs, and mud-bottomed streams as

well as in sand-bottomed rivers". *Trionyx muticus* is almost exclusively found in sand-bottomed rivers.

Discussion

Based on the present day distributions of species represented by the Clear Lake fossil turtles, the climate of the area at the time of the accumulation of the bones must not have been much colder than it is today. At present, *Chelydra serpentina* ranges north to Lake Nipigon in Ontario, and *Trionyx spinifer* ranges to about 50 miles south of the Duluth-Superior area of Wisconsin (Conant, op. cit., maps 3 and 35). But *Pseudemys scripta* occurs no farther north than Northern Illinois and Indiana, although there is a colony in southeastern Michigan (Conant, op. cit., map 24).

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Manuscript received March 10, 1966.

APPLICATION OF THE TYNDALL EFFECT TO THE EVALUATION OF THE SOLUBILITY PRODUCT FOR ALUMINUM TRIS-(8-HYDROXYQUINOLATE)

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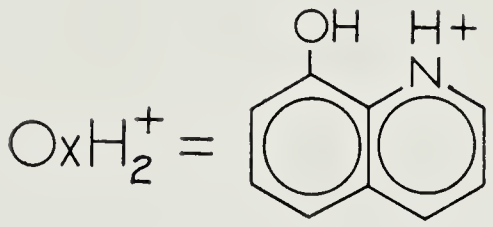
ABSTRACT.—The use of the Tyndall effect as an end-point detection technique for determining the pH of incipient precipitation yields experimental values for the solubility product for aluminum tris-(8-hydroxyquinolate) in excellent agreement with literature values. The determination is much simpler than classical potentiometric techniques and requires no special apparatus other than an ordinary electronic pH meter and a concentrated beam of light, such as that from a pencil flashlight; it is well-suited for high school or college student performance.

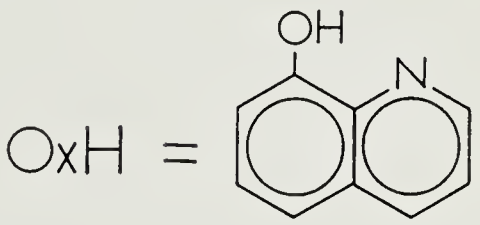
Certain metals, e.g., aluminum, iron, copper, zinc, cadmium, nickel, cobalt, and manganese, yield well-defined crystalline precipitates with the reagent 8-hydroxyquinoline (also called oxine, hydroxine, or 8-quinolinol), under certain specific conditions of pH of the precipitation medium. In general, these precipitates have the formula $M(C_9H_6ON)_n$, where n is one-half the coordination number of the metallic ion, M. Such compounds are conveniently designated by the common name *oxinates*.

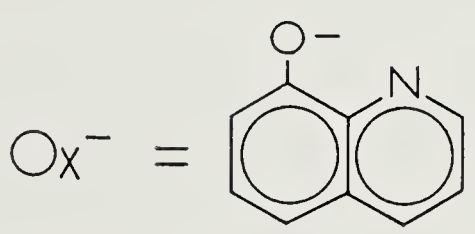
The reagent oxine is an amphoteric electrolyte, capable of functioning either as a weak base or as a weak acid, according to the reactions:

$$OxH_2^+ \rightleftarrows H^+ + OxH \qquad (1)$$
$$OxH \rightleftarrows Ox^- + H^+ \qquad (2)$$

where







In precipitation reactions with the previously mentioned metals, oxine functions as a weak monoprotic acid; the metallic ion undergoing complex formation replaces the acidic proton. Hence, for aluminum ion, the reaction in an acidic medium may be represented as

$$Al^{+++} + 3\ OxH \rightleftarrows Al\ (Ox^-)_3 + 3H^+$$

The formation of metal-oxine complexes is dependent upon the pH of the medium in which they are formed; the complex between aluminum and oxine begins initial precipitation at approximately pH 3 (precipitation is essentially complete in the range pH 4-10).

FUNDAMENTAL THEORY

In precipitation analyses, the chemist generally deals with very slightly solu-

ble salts behaving as strong electrolytes in solution. According to the classical definition of strong electrolytes, saturated solutions of such slightly soluble salts contain the complex species completely ionized into its component parts. In the case of aluminum oxinate, the equilibrium is

$$Al(Ox^-)_3 \rightleftarrows Al^{+++} + 3\ Ox^-$$

The reaction is reversible; at equilibrium, the rate of formation of aluminum oxinate is equal to the rate of its dissolution. The law of mass action yields the relationship

$$K = \frac{[Al^{+++}]\ [Ox^-]^3}{[Al(Ox^-)_3]}$$

where $[Al^{+++}]$ and $[Ox^-]$ represent the molar concentrations of Al^{+++} and Ox^- ions, respectively, and $[Al(Ox^-)_3]$ is the "active mass" of the solid salt. As long as undissociated $Al(Ox^-)_3$ is present, its active mass in the solution is constant and independent of the amount present. Therefore, the expression becomes

$$K_{sp} = [Al^{+++}]\ [Ox^-]^3 \qquad (3)$$

where K_{sp} is the solubility product constant at the temperature of measurement.

The solubility product constant expression for aluminum oxinate may be written in terms of the various species involved in the reagent equilibria. From equations 1 and 2:

$$K_1 = \frac{[OxH]\ [H^+]}{[OxH_2^+]} \quad \text{and}$$

$$K_2 = \frac{[Ox^-]\ [H^+]}{[OxH]}$$

from which

$$[OxH] = \frac{K_1[OxH_2^+]}{[H^+]} \quad \text{and}$$

$$[Ox^-] = \frac{K_2[OxH]}{[H^+]}$$

Substitution of the expression for $[OxH]$ into that for $[Ox^-]$ yields

$$[Ox^-] = \frac{K_1K_2[OxH_2^+]}{[H^+]^2}$$

Further substitution of the latter expression for $[Ox^-]$ into the expression for the solubility product constant for aluminum oxinate (equation 3) gives the relationship

$$K_{sp} = \frac{[Al^{+++}]\ K_1^3K_2^3\ [OxH_2^+]^3}{[H^+]^6}$$

which may be rewritten in exponential form as

$$pK_{sp} = -\log [Al^{+++}] + 3\ pK_1 + 3\ pK_2 - 3\log [OxH_2^+] - 6\ pH \qquad (4)$$

The relationship in equation 4 is valid whenever the oxinate is precipitated in an acidic medium, in which the oxine is present almost completely in the form OxH_2^+ (equation 1). The experimental evaluation of the K_{sp} for aluminum oxinate therefore depends on the values of K_1 and K_2 for the reagent oxine, the molar concentrations of Al^{+++} and oxine reagent selected, and the pH at which the precipitation begins (incipient precipitation).

The values of the constants pK_1 and pK_2 have been determined potentiometrically by Lacroix (1947, p. 282) and reported to be 5.09 and 9.82, respectively. Since the concentrations of aluminum ion and the reagent oxine may be fixed, the experimental evaluation of the solubility product constant becomes dependent only upon the measurement of the pH at incipient precipitation.

Experimental

End-Point Detection Techniques.—The precise detection of end-points involving the observation of the first slight turbidity in precipitation titrations is relatively accurate, but tedious in inexperienced hands (Vogel, 1961, pp. 81-3). Application of the Tyndall effect (Skoog and West, 1963, p. 164) as a means of detecting the first slight traces of suspended solid in the precipitation medium greatly increases the precision of this type of end-point detection. An ordinary spotlight, e.g., a simple pencil flashlight with the light beam passing through the precipitation medium in a direction perpendicular to the direction of observation, is quite satisfactory for this purpose. Prior to the end-point of the titration, the light beam is invisible through the solution but, as precipitation begins, the beam appears rather dramatically as a result of the Tyndall effect.

Reagents and Solutions. — The oxine reagent solution was prepared by dissolving the requisite weight of A. R. grade 8-hydroxyquinoline in about 50

ml. of M/5 HCl in a 100-ml. volumetric flask, followed by dilution to the mark with the acid. The stock solution of Al^{+++} was prepared by dissolving the requisite weight of A. R. reagent $Al_2(SO_4)_3 \cdot 18H_2O$ in distilled water containing a few drops of concentrated sulfuric acid to retard hydrolysis, followed by dilution to the desired volume. The N/10 NaOH solution was prepared by dissolving A. R. reagent in distilled water, followed by appropriate dilution. Standard pH 4.10 buffer solution was prepared from Coleman Certified buffer tablets, as directed by the manufacturer.

Apparatus.—Any commercial electronic pH meter equipped with glass indicator and saturated calomel reference electrodes is suitable for pH measurements at incipient precipitation; in this study, Coleman Model 18-A and Beckman Zeromatic instruments were used, standardized immediately prior to titrations against the standard pH 4.10 buffer. A variable aperture spotlight lamp, arranged so that the light beam passed through the titration beaker at right angles to the direction of observation, was used as an end-point detector; no significant difference was observed when an ordinary pencil flashlight was substituted for the lamp. Black construction paper placed behind the titration beaker was found to enhance end-point observation. Low-speed magnetic or manual stirring was found to be satisfactory.

Procedure.—After preliminary standardization of the pH meter, appropriate volumes of Al^{+++} and oxine reagent stock solutions were pipetted into the titration beaker. An accurately measured volume of distilled water was then added to increase the volume of the solution to a convenient level, if necessary. The titrations were accomplished by the addition of the NaOH solution from a buret—end-points of separate titrations were detected by normal and Tyndall effect observations of incipient precipitation. The pH value of the sample solutions at the end-points were recorded, as were the volumes of NaOH added; the total volume of solution at the end-point was obtained by simple arithmetical addition (to the nearest 0.5 ml) of all reagent and water volumes contributing to the final mixture. The temperatures of the titration mixtures at the end-points were observed and found to be 27 ± 2°C (room temperature) in all instances. Each titration required 15-30 minutes for completion.

Results and Discussion

The results of pK_{sp} evaluations for aluminum oxinate at room temperature for normal and Tyndall effect end-point observations are shown in Tables 1 and 2, respectively. End-points detected by normal visual observation were characterized by the initial appearance of a faint opalescence throughout the solution. The appearance of the Tyndall effect end-point was not only relatively sharp, but also somewhat earlier than normally observed end-points. In all instances, the pK_{sp} values were calculated by substitution of the experimental data into equation 4, along with the literature values for pK_1 and pK_2 previously given.

The pK_{sp} values shown in Tables 1 and 2 correspond to K_{sp} values of 4.1×10^{-30} and 3.5×10^{-31}, respectively, for normal and Tyndall effect end-point observations. These correspond with literature values, determined potentiometrically, of 5×10^{-33} (Lacroix, 1947) and 5×10^{-31} (Borrel and Paris, 1952). The value obtained through Tyndall effect end-point observation is not only more accurate than the normally observed one, but also more precise; the pK_{sp} data for the Tyndall effect experiments show a standard deviation of 0.40, as compared with 0.75 for the normal observations. The confidence limit, at the 90% probability level, for the pK_{sp} results shown in Table 2 is 30.45 ± 0.20.

An experiment based on the precipitation of aluminum tris-(8-hydroxyquinolate), or any of the other readily precipitated metallic oxinates, may be adapted quite readily to student performance. Other organic precipitating agents, such as dimethylglyoxime for nickel, which operate in a manner similar to 8-hydroxyquinoline may also be studied. In most instances, literature values for corresponding K_{sp}'s are available for comparison of results. In cases involving divalent metals, an equation analogous to equation 4 must be derived by the experimenter for evaluation of the solubility product constant from experimental data.

Acknowledgments

The authors are grateful for financial support from the Cooperative Research in Chemistry Project of the Carbondale Campus of Southern Illinois University.

TABLE 1.—**Solubility Product for Aluminum Oxinate Calculated from Normal Visual Observation of Incipient Precipitation. $[Al^{+++}] = 0.033$ M, $[OxH_2^+] = 0.095$ M.**

Solution Composition			Final Volume ml.	pH at Incipient Pptn.	pK_{sp}
Al^{+++} ml.	OxH_2^+ ml.	H_2O ml.			
10.0	10.0	0	31.5	3.82	28.35
			31.0	3.45	30.53
		10.0	43.0	3.65	29.92
			44.0	3.82	28.94
		20.0	49.0	3.55	30.73
			48.0	3.80	29.19
		30.0	61.5	3.89	29.09
			61.5	3.88	29.15
20.0	20.0	10.0	70.5	3.70	29.27
			72.0	3.85	28.41
10.0	20.0	20.0	69.5	3.75	29.23
			71.5	3.65	29.91
					Mean: 29.39

TABLE 2.—**Solubility Product for Aluminum Oxinate Calculated from Tyndall Effect Observation of Incipient Precipitation. $[Al^{+++}] = 0.033$ M, $[OxH_2^+] = 0.095$ M.**

Solution Composition			Final Volume ml.	pH at Incipient Pptn.	pK_{sp}
Al^{+++} ml.	OxH_2^+ ml.	H_2O ml.			
10.0	10.0	0	31.0	3.41	30.77
			30.0	3.48	30.31
		10.0	41.5	3.52	30.63
			40.5	3.62	29.99
		20.0	48.5	3.58	30.55
			52.0	3.52	31.03
		30.0	61.0	3.71	30.17
			60.5	3.70	30.19
20.0	20.0	10.0	71.5	3.62	29.79
			70.5	3.56	30.11
			71.5	3.50	30.50
10.0	20.0	20.0	70.0	3.45	31.07
			66.0	3.48	30.77
					Mean: 30.45

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Manuscript received February 14, 1966.

ANALYSES OF THE EFFECTS OF FOUR COMPONENTS IN CIGARETTES ON *PARAMECIUM AURELIA*

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ABSTRACT.—Methods were described for testing the toxicity of aqueous solutions of cigarette tobacco, cigarette smoke, cigarette ash, and ash of cigarette paper, utilizing a Kappaless *Paramecium aurelia* as the assay organism. Observations were made on populations of this organism in 1 ml of each of these solutions from 1 non-filter cigarette. Overall toxicity, based on survival time, of these cigarette components was found to increase in this order: paper ash, whole ash, smoke and tobacco. In reality, however, the smoke is most toxic since only a small fraction of the smoke from one cigarette was used in the experiments. Solutions of tobacco and smoke both were completely lethal to the protozoon in that they brought quick death to every organism in a population. There was neither body deformation prior to, nor disintegration after, death. A unique "polar blistering" was observed in case of the tobacco solution. Solutions of whole cigarette ash and paper ash both brought erratic changes in the organism's motility pattern; they also imparted an incomplete lethality to the population. But while the paper ash solutions caused pronounced body deformation and severe blistering followed by disintegration, solutions of whole cigarette ash characteristically elicited a dislocating clumping of endoplasmic granules, leading to death. The sensitivity of *Paramecium aurelia* to cigarette toxicity was further evidenced by its "ability" to distinguish, by virtue of clear-cut differential reaction patterns, solutions of whole cigarette ash from those of tobacco ash alone. These results did not vary significantly from one brand of cigarette to another. It is suggested that the organism's different reaction patterns to the cigarette components may possibly be related to certain specific chemicals in which the tested components differ from each other.

Two previous reports (Wang, 1959 and 1960), especially the latter, indicated that *Paramecium aurelia* is not just chemically sensitive, but that it is capable of differentiating various chemical stimuli in its environ by means of certain set patterns in both behavior and morphology. These observations, plus the consideration that the protozoon is a cell and an organism at the same time, prompted me to use it as a test organism for cigarette toxicites (Wang, 1963a). Since then, more observations on the reaction patterns of *Paramecium aurelia* elicited by each of the four cigarette components have been made. Part of these efforts has resulted in a cinematographical study: the death of *Paramecium aurelia* from cigarette paper toxicites (Wang, 1963b). The purpose of this report is two-fold: (a) to present a more detailed record of how *Paramecium aurelia* was affected by each of the four cigarette components in both quantitative and qualitative terms with special emphasis on its reaction pattern to the cigarette paper ash, and (b) to publicize once more that *Paramecium*

aurelia is a useful assay organism for tobacco and other toxicity studies.

Material and Methods

Six domestic and one imported (from Taiwan) brands of non-filter cigarettes were used in this work. Cigarettes were smoked with a simple artificial device. It utilized a conventional suction filter flask attached to a tap faucet and with a two-hole rubber stopper replacing the filter funnel. To one end of the tube leading into the flask was fitted a cigarette holder while the other (inside the flask), was dipped into a test-tube holding 20 ml water. A cigarette was inserted into the holder and lit; water was turned on with its pressure so adjusted that a cigarette was steadily consumed within three and a half minutes, leaving a butt of approximately 10 mm. During this process the mainstream smoke bubbled through the water. Much of it escaped into the flask; only a fraction was dissolved in the water. In view of the low solubility of smoke and the particular method here used to attain its solution, this amount was estimated to be under 5 per cent of the total smoke produced. The resulting cigarette ash was collected in a beaker, 20 ml water was added to it, and was filtered after one hour.

For preparation of tobacco and cigarette paper solutions, a cigarette was separated into tobacco and the wrapper. The former was placed in 20 ml water and was likewise filtered after one hour. The cigarette paper was burned in a porcelain tray with a Bunsen flame directed at it for one minute. The resulting ash (white) was placed in 20 ml water, and similarly filtered.

A paperless ash was prepared for comparison with regular ash. It was made by carefully stripping the paper off a well burning cigarette, allowing the tobacco to burn to completion undisturbed. The resulting ash (of tobacco only) was processed exactly as in the case of regular cigarette ash.

Twenty ml solutions were thus prepared from each of the four cigarette components: tobacco, smoke, whole, and paper ash. They constitute our standard stock solutions. For each experiment, 1 ml of a standard solution, arbitrarily designated as having a concentration of 1.0, was utilized. This concentration was found through repeated testing to be the most useful for our experiments.

An experiment was run in the following manner. The 1 ml test solution was transferred to a depression slide (3″ x 1¾″) with a central 1⅜″ concavity. To it was added 2 drops of paramecia from a flourishing culture. The fine micropippete used for this purpose had a caliber (at mouth) that 40 drops are equal to 1 ml. Samples were only taken from sufficiently dense (luxuriant) populations, e.g., one pippete drop contained several hundred paramecia.

Raw rice was used for culturing. It proved to be a better source of bacteria than oat grains used previously by us. Ten grains of rice were added to 25 ml water in a sterilized Petri dish, and seeded with a dropful of paramecia. It took, on the average, 10 to 14 days for a culture to reach maximum density and can be maintained in that condition for two weeks or longer, depending on the temperature. New cultures were periodically grown in order to have a continuous supply on hand.

Observations using an AO-Spencer cycloptic stereo-dissecting microscope were made beginning from the time paramecia were introduced into a test solution until death resulted. The duration was recorded as survival time which was used as a basis for rating the overall lethality of a test solution. Criteria of death were cessation of all movements (cilia, contractile vacuoles, and endoplasmic streaming) and stoppage of all signs of life.

Close attention was given to changes in motility and morphology of the organisms. Permanent records of the morphological manifestations were made with both light and phase microscopy. While most changes could be readily photographed, certain types of deformities, because of the incessant motion of the affected organisms, were rather difficult, if not impossible to photograph. Generally, light photomicrography was used for groups of paramecia under low magnifications (Figs. 1, 2, 3, 4, 6, 7, 8) while individual organisms of interest were photographed with phase microscopy at much higher magnifications on a ZEISS-WL research microscope with Neofluar 25X and 40X objectives (Figs. 5, 9, 10, 11, 12, 14, 15 and 16 through 28). Figures 16 through 29 are prints made from negatives of 35 mm. Kodachrome transparencies.

A procedure for making preparations for photomicrography was adopted. Under the binocular dissecting microscope and with a micropippete of even a smaller caliber than the one used for transferring paramecia to experimental solutions, the affected organisms were

removed to a clean slide. In order to avoid crushing the organisms, four pieces of glass chips from a broken coverslip were carefully placed along the edge of the drop before a coverslip was placed over it. With glass chips thus serving as support for the coverslip, the preparation was insured against artifacts, which might result from mechanical pressure.

Experiments were carried out at room temperature, 23 to 31° C. This is a safe range within which the organisms' responses may vary, but only in degree of intensities. Usually, an increase in either temperature or concentration of the solution shortens the survival time, accelerates the movement and increases the extent and/or speed of disintegration following death. It has been ascertained that temperature variations within this range would not change the nature of the reaction patterns of *Paramecium aurelia* to any appreciable degree. In the experiments, pH of all solutions including distilled water and culture media were determined on a pH meter (Beckman, Model H2). The range used was pH 5.0 to 8.0, which has proven safe, i.e., harmless for this organism. Water used for all purposes in this work was chemically pure, obtained from an automatic Pyrex distiller (Stokes, Model 171-E). For double safety this water was periodically checked to make sure that it was not the least toxic to the experimental organism used.

Results

The results show that the seven brands of cigarettes used presented a range in survival time, which is not widely spread. The observed narrow range could mean only one thing, namely that there are no significant differences between the brands as far as toxicity to paramecia is concerned. On the other hand, the overall toxicity of the cigarette components as measured by survival time was statistically significant. It was 8, 14, 21 and 27 minutes at 23° C and 4, 5, 10, and 12 minutes at 31° C for, respectively, tobacco, smoke, whole ash and paper ash.

One observation deserves special mention: the paramecia were killed in tobacco and smoke solutions significantly faster than in solutions of whole ash or paper ash. The difference may be taken as evidence of a greater overall toxicity of the former two cigarette components. In relation with this, another phenomenon was consistently observed. That is, the two weaker components (whole cigarette ash and cigarette paper ash) were not able to kill an entire population of experimental animals, but invaribly a few paramecia survived. These survivors remained totally unaffected and healthy throughout the experiment. In fact, they were found to be able to give rise to new individuals by fission after the experiment. Using this as a criterion, the four cigarette components, at the concentration used in the experiments, may be divided into two groups, namely those which are completely lethal (tobacco and smoke) and those which are incompletely lethal (whole and paper ash) to *Paramecium aurelia*. From this, the importance of using a critical concentration for the test solutions is easily realized.

The remainder of our data concern with motility and morphology of the affected animals. The observations to be presently described were based on many more experiments than those from which survival time was obtained. The experiments were carried out at concentration 1.0, unless otherwise stated, and within a temperature range of 23 to 31° C.

Observation on Motility

Two general patterns of modified motility were observed. With tobacco or

smoke, the organisms became quickly quiesced, ending in complete cessation of motion within few minutes. Whole ash or paper ash, on the other hand, elicited an opposite effect. It was one of energization, excitation, and stimulation. The paramecia seemed to be activated on contact with the test solution and immediately began to move around at a high tempo in manners deviating from the normal. At first, the induced motility pattern took on an accelerated "avoiding reaction" (Jennings, 1906). The animals swiftly zig-zagged, changing directions repeatedly as if to avoid some adversity. Soon this subsided, and it was replaced by several peculiar types of motion. Some of them began to swim "pin wheel" fashion. Others moved forward spirally with the anterior end whirling a complete circle. Still others exhibited a vibrating or oscillating type of motion at the posterior end as the organism slowly propelled ahead. And all these patterns could be present simultaneously so that the composite motion of the population of affected paramecia was bizzare and really beyond description. What has been said can be applied equally well to the ash solution of a whole cigarette or of the paper only, generally to a greater degree in case of the whole ash. Just prior to waning of these induced movements, morphological changes set in, leading finally to death of the animal.

Observation on Morphology

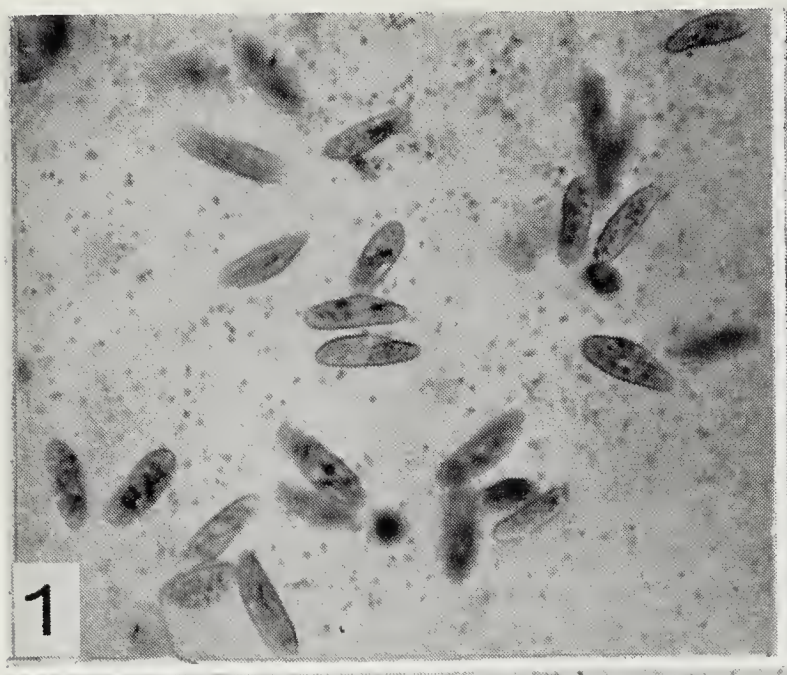
Tobacco. The action of tobacco solution was lethal to paramecia. Death was not preceded by conspicuous morphological changes aside from an occasional mild shrinkage (Fig. 7). The occurrence of shrinkage was indicated by a flattening of the body, frequently into the thinness of a leaf. Such an effect could be clearly seen in a moving (rotating) paramecium, but is not so obvious from a still photograph. In addition, a good portion of the population extended an ectoplastic blister (in most cases only one) from either end of the animal (hence the term, polar blistering, as seen in Fig. 7). The differences betwen this kind of blister and those characterizing the effect of paper ash can be learned by comparing Figure 7 with Figures 3, 11, 13 and 14. As a rule, the bodies of dead organisms remained fairly intact, undergoing little disintegration if at all.

Smoke. The action of this cigarette component was also lethal. Death came about quietly and quickly to the entire population like a sweeping lethal wave (Fig. 2). The dead organisms appeared somewhat swollen (cf. Figs. 1 and 2, same magnification) with some postmortem disintegration, the amount of which seldom exceeded the extent indicated in Figure 4. At higher magnifications, however, certain damage done to the endoplasmic granules and the derangement of cilia were visible (Figs. 9 and 10). A conspicuous feature was the translocation of endoplasmic granules toward one end of the cell. These were relatively mild deformities compared to what will be described below for the toxic effect of cigarette paper ash.

Ash. As described above, its effect on motility lasted only a few minutes. The activated organisms finally slowed down, came to a standstill and started to succumb. Their endoplasmic granules at this time exhibited a conspicuous aggregation, most of them being localized around the macronucleus (dark granules in Fig. 6 and Fig. 29).

This is a characteristic reaction pattern seen in solutions of whole cigarette ash or the ash of paperless cigarette (i.e., tobacco ash alone). The noteworthy thing is that we have been able to distinguish the reaction of *Paramecium aurelia* to these two kinds of ash solutions. Thus, in the former, the dead organisms underwent body-swelling and disintegration (Fig. 6) to a noticeably greater extent than seen in the latter (Fig. 8). Another difference was in connection with a mild form of trichocyst exposion occasionally seen from dead or dying paramecia. The released trichocysts seen as extremely fine dark fibrils with phase microscopy appeared always associated with the cytoplasmic debris resulting from the disintegrated organisms. The trichocysts and this debris seemed to have an affinity for each other, and the resulting products of mingling made up a gluey mass. The latter was distinctly thicker in the solution of a whole cigarette ash than in the solution of tobacco ash alone. This ability of *Paramecium aurelia* to differentiate the toxic action of these two kinds of ash solutions probably has a chemical basis (see discussion).

Paper. The most unique feature of the action of cigarette paper ash is that it produces the most severe and extensive deformations (Figs. 3 and 11 through 28). A small proportion of the population was killed in the first few minutes following exposure. These ani-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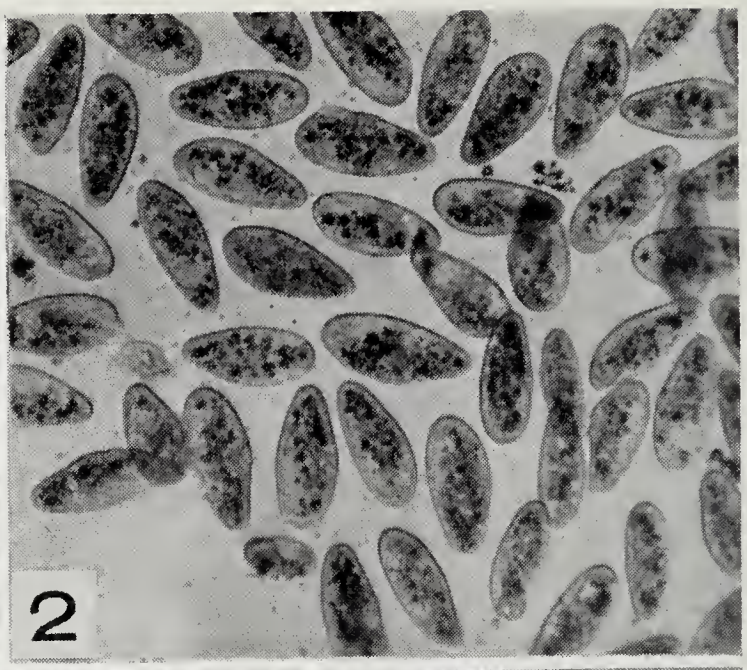
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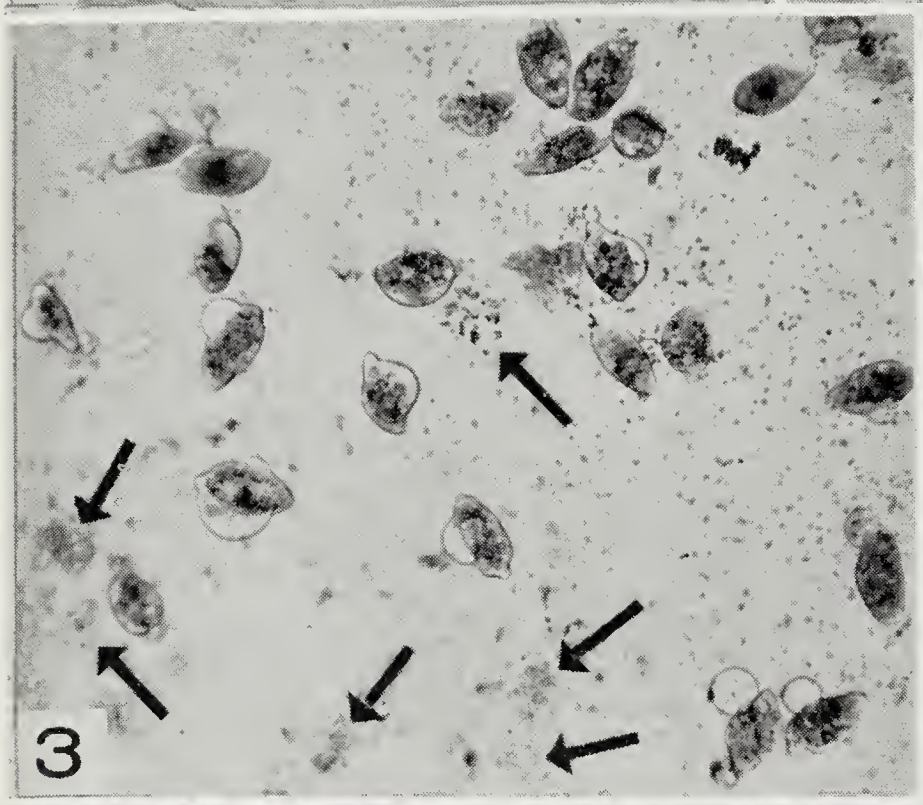
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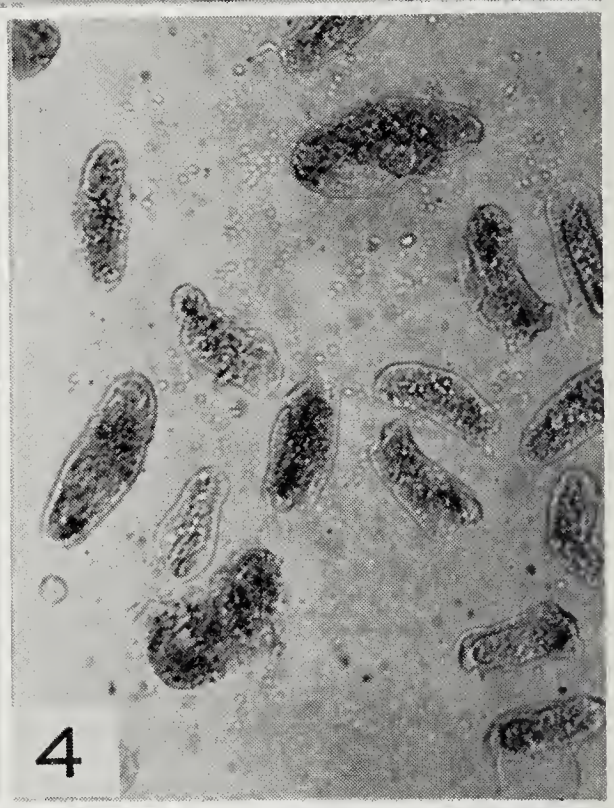
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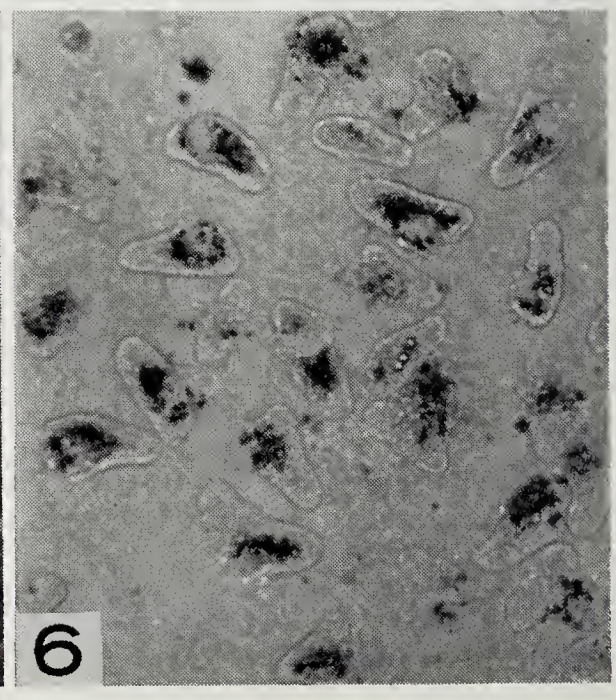
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mals virtually exploded into a mass of cytoplasmic debris (Figs. 5, 15). About half of the population, being the next weakest, became severely affected within the next few minutes. There appeared, as though, a wave of destruction had suddenly struck them, and that the wave quickly spread and overtook the individuals with bursting disintegration. Some of their remains ("ghosts") are shown in Figure 3 (arrows). In this photograph taken 12 minutes after immersion, there were two groups of paramecia: those that have had long since succumbed and undergone advanced disintegration and those which displayed body deformation of one kind or another coupled with extensive blister formation.

The blisters, when first formed, were of the ectoplasmic type filled with a gel of the same consistency as the cortex. One organism may bear more than one blister, and the blisters once formed would proceed to undergo changes in size and composition. In most cases blistering paramecia remained active for some time, moving around in strange erratic fashions that defy adequate description. The best one can hope to do (next to seeing the motion picture: Wang, 1963b) is to record a variety of their morphology with phase photomicrographs (Figs. 11 through 14; 16 through 28). The blisters shown in most of these illustrations are of the ectoplasmic kind. A few endoplasmic blisters are shown in Figures 12, 20, 24, 27, and one in Figure 3, close to the right-had edge. I am reasonably certain that all blisters started out as ectoplasmic blisters. Most of them, however, underwent a sequence of changes, eventually transformed into endoplasmic blisters before they finally burst open and collapsed. The events of this transformation can be seen in a single organism, which bore two blisters shown in the process of this transformation (Figs. 16, 17, 18). See also Figures 12, 19 and 20.

One extreme deformity occurring only in solutions of cigarette paper ash was a combination of blistering and body protrusions (Figs. 14, 21, 23, 25, 27, 28). The latter were cytoplasmic evaginations of various size, shape, and loci. One such protrusion was formed on a banana-shaped body (Fig. 28), another, on a sausage-shaped body (Fig. 24). Paramecia of this monsterly appearance with one or more blisters characteristically moved around not only in most strange ways, but with a rhythmic beat. The latter is probably attributable to the greatly disturbed weight distribution (Figs. 20, 22, 25, 27) with the apparent result that gravity takes over the control of body movement, a function which is normally executed by the cilia.

Distinct differences between body protrusions and blisters can be recognized. The former, from the time of inception and throughout their existence, contain no appreciable amount of ectoplasm, and may be of any size and shape (Figs. 19, 20, 25, 27, 28). The shape may change from time to time (cf. Figs. 19 and 20), but never assume a spherical contour. On the other hand, a blister, regardless of its content (ectoplasmic, Fig. 19; endoplasmic, Fig. 22; or with

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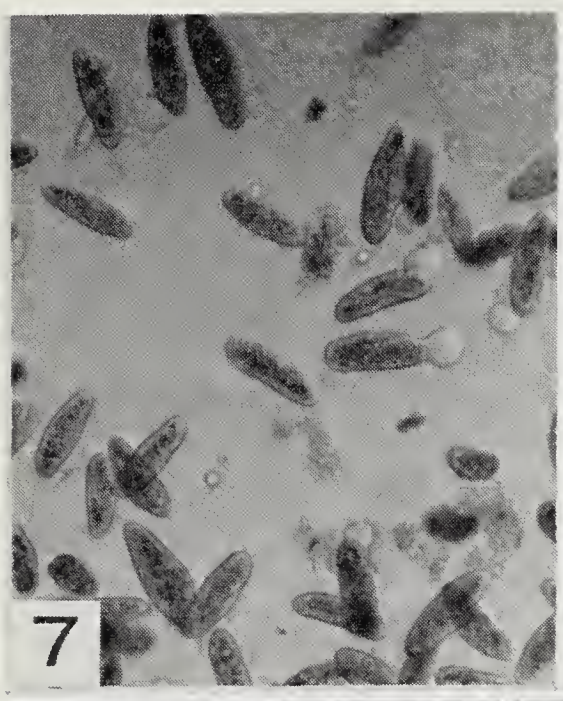
Figures 1-6.—Illustrations of paramecia. 1. Control: live paramecia taken with 1/50 sec. exposure (not fast enough to catch them all in sharp focus). Note variation in body size and other features. (X85). 2. Dead intact paramecia in smoke solution, 20 minutes after immersion. The plumpness (approximately twice the width and 30% longer than controls in Fig. 1) was the result of increased permeability. (X85). 3. Paramecia in cigarette paper ash solution, 12 minutes after immersion: those that still had intact bodies with or without blisters and those which had already been dead, leaving "ghosts" and cytoplasmic debris at spots (arrows). Most of the blisters born on intact organisms were of the ectoplasmic type. (X85). 4. Portion of the preparation shown in Figure 2, taken 45 minutes later, showing still intact but considerably flattened-out bodies. Note: magnification of this figure is X120 as compared to Figure 2, X85. 5. Phase micrograph of 4 paramecia from the same preparation shown in Figure 3, 25 minutes post immersion (13 minutes after Fig. 3 was taken). The 4 organisms could be any of the blistering organisms shown in Figure 3: the lower two already burst open, the upper two, about to disintegrate. The thick granular material filling the background constituted a debris from disintegrated organisms. (X260). 6. Dead paramecia in cigarette ash solution, 10 minutes after immersion: 1 or 2 organisms still intact; most others already burst through at one point. Note the aggregated dark cytoplasmic granules in the cells, some of which had been liberated from the burst cells. (X85).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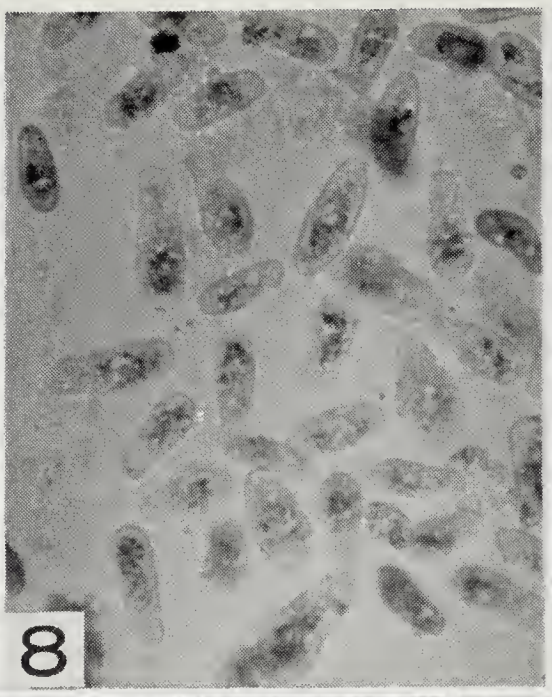
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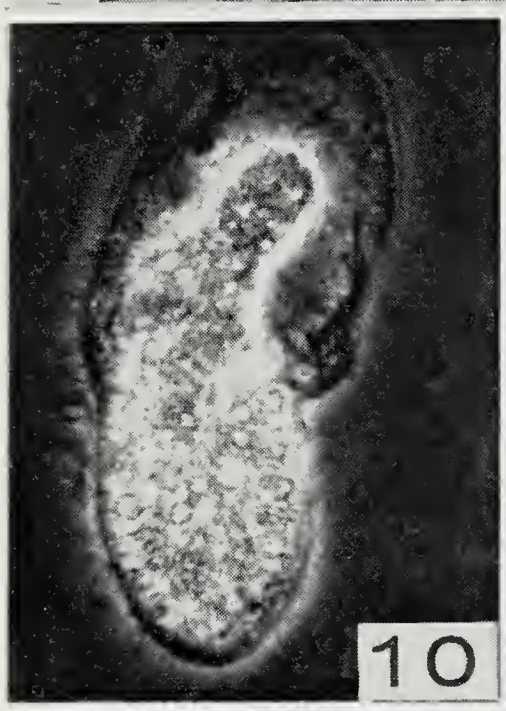
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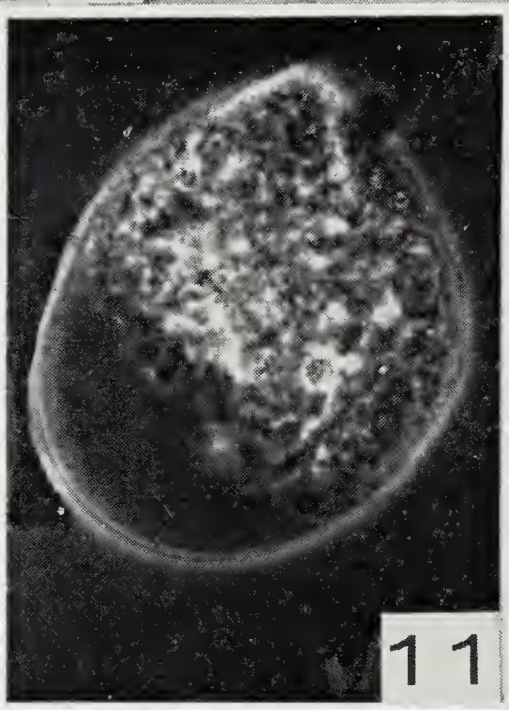
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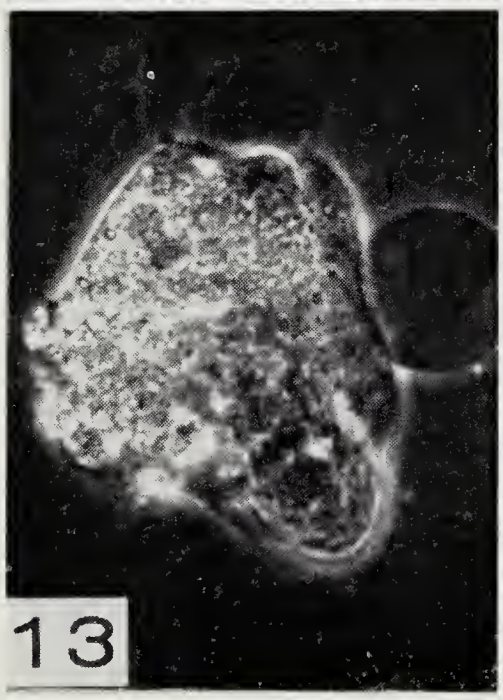
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both, FIGS. 25 and 27) had the unique feature of possessing a round contour. The contrast between the endoplasmic blisters as shown on top of both FIGURES 22 and 23 and a body protrusion as shown in FIGURE 25 seems quite conceivable. Yet another case is illustrated by FIGURE 27, which shows a small limb-bud-like protrusion next to a half-circle endoplasmic blister and two distinct ectoplasmic blisters (one large and one small) in addition.

It was not always possible to follow the fate of the deformed blister-bearing paramecia. In most cases the terminal events were characterized by an impeded ciliary motion. Such organisms lacked the normal wavy unison beat of cilia. Soon a rupture occurred at some spot or point (not necessarily on either end of the animal), and this was quickly followed by disintegration. The cell was virtually blown up to pieces, ending in complete cytolysis. All this happened very fast and the preparation became clogged up with thick cytoplasmic debris (FIG. 5). Concomitantly, the blisters yielded and vanished without leaving a trace (FIG. 18). It appears as though blisters can be maintained only on an intact body. A break-through anywhere on the surface of the body brought instant collapse to them. Meanwhile, as mentioned above, a small portion of the population remained totally unaffected. These resistant organisms, like those encountered in the solution of whole cigarette ash, survived unharmed. Moreover, these survivors displayed the remarkable resistance to the action of the ash solutions from the start of the experiment. Once a paramecium came under the sway of the toxic action, it would proceed all way to death. Acclimatization to or recovery from the deleterious effects of cigarette toxicities has not been observed.

DISCUSSION

Paramecium, an ideal assay organism. If this study has contributed anything to our understanding of cigarette toxicities, it was made possible by the fact that *Paramecium aurelia* happens to be a cell and organism at the same time. As such, it permits the worker to obtain data of both quantitative and qualitative nature from the same experimental setup. This is a condition, which constitutes a unique advantage in using protozoa as assay organisms. The same cannot be said of metzoa employed similarly in toxicity studies.

The results have shown that *Paramecium aurelia* is not killed alike by all cigarette components; rather, it succumbs to the toxicities at different rates and with different manners. This denotes that both quantitative

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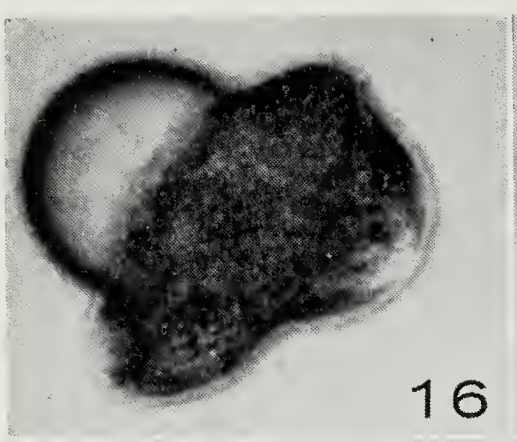
Figures 7 - 15. — Illustrations of paramecia. 7. Dead paramecia in tobacco solution, 25 minutes after immersion: most of them, different from normal controls (FIG. 1); about a third of them bore an ectoplasmic blister on either end of the animal. Compare with FIGURE 3 for difference in the nature of blistering. (X85). 8. Dead paramecia in paperless ash solution, 10 minutes after immersion. Note body deformed to a milder degree than those in FIGURE 6, however, with the same kind of aggregation of endoplasmic granules. Some of them would have subsequently disintegrated following the same manner indicated in FIGURE 6, but to a lesser degree. (X85). 9. Dead paramecium in smoke solution, 30 minutes after immersion, portraying typical morphological deformation pattern effected by smoke. The animal remained intact with endoplasmic mass translocated toward one end, and revealing rows of "pits" on the pellicle from which the cilia (deranged) extended. (X450). 10. Another paramecium of the kind shown in FIGURE 9, showing again deranged cilia and translocated endoplasm, and the longitudinal rows of cilia pits. (X450). 11, 12, 13 and 14. Paramecia from cigarette paper solution showing different types of blistering and body deformation photographed just prior to onset of disintegration. The blisters shown in FIGURES 11 and 13 were of ectoplasmic type while that in FIGURE 12 was endoplasmic. The latter appeared to have just been transformed from an ectoplasmic blister. The paramecium in FIGURE 13 assumed the shape of an ameba. The one in FIGURE 14 had blisters of both types, though predominantly ectoplasmic. (X450). 15. A disintegrating paramecium from cigarette solution, 14 minutes after immersion. (X450).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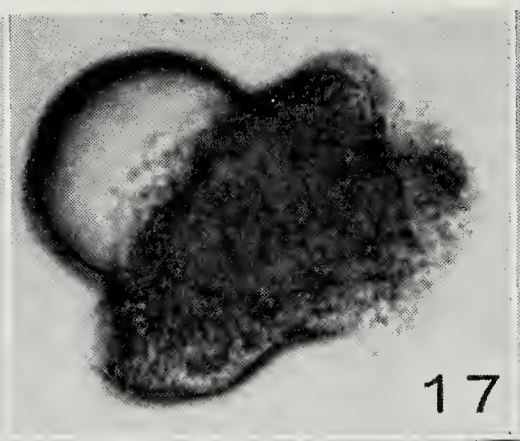
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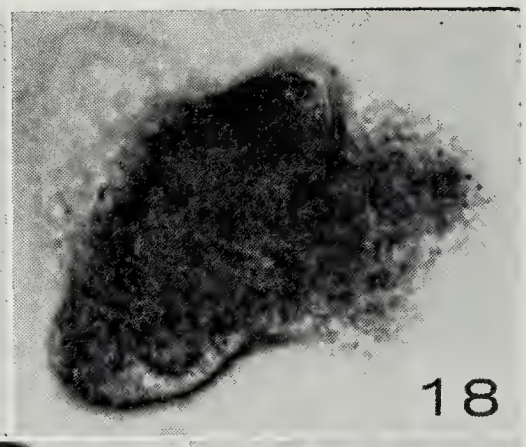
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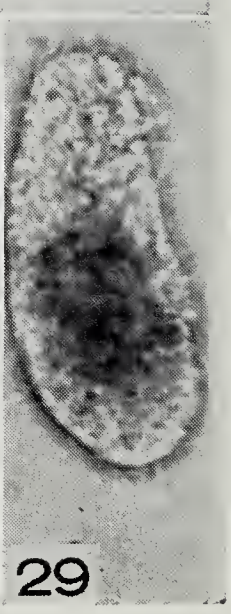
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and qualitative factors were at work. These factors were assessed, respectively, as survival time and manifestation patterns. The former served as an index of lethality while the latter portrayed the exact ways in which death of the animal came about. Evidently, both kinds of data are useful; but, only the latter kind qualify as diagnostic criteria pertinent to investigations of this kind.

Other examples of quantitative factors were temperature and concentration of the test solutions. They affect only the rate or intensities of chemical processes (rate of induced motion, extent of postmortem disintegration, extensiveness of blistering, etc.), definitely not the nature of reaction patterns. But when temperature and/or concentration are raised to such a level that death of the organism becomes almost instant, the animal would have no chance to react. This is exactly what happened in solutions of cigarette paper ash at a 3.0 instead of 1.0 concentration, and at 32° C. or higher. Under these circumstances paramecia simply burst to pieces upon immersion. The adoption of the standard 1.0 concentration throughout the work was thus a necessary prerequisite for making sure that the ensuing results would be the most meaningful.

Basis for interpretation of results. Cigarette toxicity stems from a multitude of chemicals and certain extrinsic factors peculiarly inherent in cigarette smoking (Ermala and Holsti, 1956; Green, 1955; Lam, 1955). Together, they constitute a material basis for a causal relationship between cigarette smoking and lung cancer (Carruthers, 1960; Boyland, 1964; Flory, 1941; Ochsner, 1955; Watson and Conte, 1954, 1955; Wynder et al., 1953, 1955). One is impressed with the long list of chemical constituents identified from each of the cigarette components (Kenna-

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Figures 16 - 29. — Illustrations of paramecia. 16, 17 and 18. One and the same paramecium, respectively, 2, 2½, and 3 minutes after immersion in a 2.0 conc. cigarette paper ash solution at 24° C., showing the collapse of two blisters, one following the other. The sequence of events can be readily traced. (X400). 19 and 20. One and the same paramecium, taken 7 minutes apart (cigarette paper ash solution at 27° C) during which time an ectoplasmic blister was converted into an endoplasmic one. (X400). 21. A monster paramecium, 12 minutes after immersion in paper ash solution, illustrating combination of body deformation and blistering. (X400). 22. Another paramecium from the above preparation showing a large polar endoplasmic blister. (X400). 23. A deformed paramecium 9 minutes after immersion in cigarette paper solution, bearing an ectoplasmic and an endoplasmic blister at opposite poles. (X400). 24. Another organism from the above preparation, showing a huge ectoplasmic blister and another in the process of being converted into an endoplasmic blister. (X400). 25. A deformed paramecium with a handle-like protrusion at one side; the two spherical things at left are not blisters, but were an air bubble and a small unidentified protozoon. (X400). 26. A sausage-shaped paramecium bearing two blisters of different sizes, the larger of them having already incorporated some endoplasmic granules (10 minutes in cigarette paper ash solution). (X400). 27. A paramecium with irregularly deformed body showing two blisters of contrasting sizes, one endoplasmic blister and one tiny limb-bud-like body protrusion (12 minutes in cigarette paper ash solution). (X400). 28. Another organism from the above preparation with a banana-shaped body and two ectoplasmic blisters, showing one end of body (lower) already disintegrating. (X400). 29. A dead yet intact paramecium in whole cigarette ash solution (6 minutes at 23° C) showing central aggregation of endoplasmic granules and deranged cilia. (X375).

way and Lindsey, 1958; Cummins et al., 1954; Cooper and Lindsey, 1955) and especially the fact that no two components have exactly the same chemical composition. In the light of this knowledge it would seem reasonable that the present results be interpreted as reflecting this tremendous chemical complexity. That is to say, each of the reaction patterns given by *Paramecium aurelia* possibly could be caused by a different yet specific array of chemical compounds. Certain of them bring quick death, others induce strange motility patterns, yet others alter body form and cause blistering, and so on. Somehow we must recognize that this animal is endowed with the incredible ability to detect the presence of various chemicals and respond to them accordingly. The sensitivity of such responses is best illustrated by its ability to distinguish whole cigarette ash from the ash of tobacco alone.

Causation of death. Pursuing this line of reasoning further, a line may be drawn between factors which are directly lethal to paramecia and those which cause death of the animal only indirectly. The best examples of the former were furnished by the action of tobacco and smoke, both of which inflict death quickly and completely (with no survivors) showing little or no accompanying damage. There must be present in these solutions some very toxic substances so that the animals were killed before they had a chance to react otherwise. On the other hand, chemicals present in the ash solutions (whole or paper) at the concentration used are apparently not lethal in the strict sense, but that they primarily cause certain structural changes and that death finally comes as a result of these changes, e.g., clumping and dislocation of endoplasmic granules in whole ash solution and the bursting of deformed blistering bodies in paper ash solution. The fact that both of the ash solutions induced changes in the organism's movement suggest that the same chemicals responsible for this are present in both. It is thus evident that death in these latter cases resulted from an impairment or drastic disruption of some vital function. One recalls also that the survivors (resistant paramecia) were present only in these ash solutions, suggesting that the directly lethal factors are the more toxic agents as compared to those which cause death indirectly. There is no apparent correlation between how quickly an organism succumbs and in what manner its death comes about.

Premeability changes, an important factor. Many chemicals are known to affect the permeability of plasma membrane one way or the other (Heilbrunn, 1952, 1956). These effects were indeed frequently seen in our experiments: a mild shrinkage in tobacco solution (Fig. 7), moderate swelling in smoke solution (Fig. 2 and 4), and in whole ash solution (Fig. 6). It is reasonable to suppose that in all these instances the effect (whether due to an increased or decreased permeability) could be lethal. In the final analysis, a change in permeability may act as a common denominator also for body deformation and blistering. Most blisters such as those occurring in paper ash solutions begin as ballons of pure ectoplasm (gel). Haas (1953) in his work with the slime mold called them

"hyaline extrusions" for this reason. In this paper I preferred a more neutral term, "blister", because there were blisters which contain endoplasm (Figs. 12, 22, 24, 27). In details, the blisters caused by metallic ions (Wang, 1959), by the proteolytic enzyme, ficin (Wang, 1960) and those involved in the present investigation are not exactly the same. They also differ from those of "blebbing" described by Cooper et al., 1962) and "bubbling" of cells in tissue cultures (Buchsbaum and Kontz, 1944). In the latter, relative fluidity of a surface protoplasm featured as a dominant factor. Presumably, therefore,blistering and similarly related phenomena could be brought about by a variety of factors, chemical as well as physical. They may be ions of many kinds acting at any point of the cortex, particulate matters of the dimension of a colloid, or certain physical stimulus or condition such as gas-membrane interface (Cooper et al., loc. cit.) to name just a few. In all these instances the common denominator for the phenomenon seems to be one which is intricately associated with sol-gel relationship of the cell surface (cf. Landau, 1960).

Practical significance of the results. Aside from the fact that *Paramecium aurelia* has proven itself a sensitive indicator for cigarette toxicities, the mainstream smoke was found to be the most toxic of the cigarette components analyzed. This finding is of significance because it agrees with the concensus of opinion on this subject, and that it is the smoke which comes into direct contact with cells lining the entire respiratory tract. Various deleterious effects of smoke on the epithelial cells (ciliated) of the tracheobronchial tree are known (Hilding, 1956; Chang, 1957; Ide et al., 1958). More specifically, the cilia of these cells are most directly affected, leading to complete cessation of their activity followed by disintegration (Ballenger, 1960; Tremmer et al., 1959; Falk et al., 1959; Kotin and Falk, 1960). The use of a ciliate protozoon, and other animals (Guillerm, 1961) will aid us in our understanding of this vital subject without necessarily implying that their findings may be directly compared to those from human. Neither this work nor any other of this series (Wang, 1965) intends in the least to relate the results obtained from the protozoon, *Paramecium aurelia,* directly for considerations of similar studies on the human. Yet one finds it difficult to resist the reminder that all cilia, regardless of origin and kind, do have a basic similarity in structure and function (Gibbons, 1961; Sotelo and Trujello-Cenoz, 1959). The adverse effects of cigarette smoke on the cilia of paramecia (Figs. 9 and 10) has been recently confirmed by Weiss and Weiss (1964). In this connection, Thayer and Kensler (1964) reported the effectiveness of filter in reducing the deleterious effect of smoke.

A basic biological problem: resistance of some paramecia to cigarette ash and paper ash solutions. The phenomenon of resistance offered by certain individuals of a population to the action of cigarette and paper ash solutions is interesting, but so far no satisfactory explanation can be given except that it is regarded as an indication that the overall toxicity

of these solutions is below that of tobacco and smoke solutions. Protozoologists are generally aware of the fact that the behavior of *Paramecium* and other unicellular organisms is conditioned by the physiological state of the organism at any given moment. This situation may well apply to the present case. It is possible that the phenomenon of resistance to a toxicity simply reflects the degree of "vigor" or "state of general health" of the animal at the time. There are many factors which presumably determine this vigor. They are size, and age of the animal, nutritional state (food availability), and others. These are all somatic factors, which may vary a great deal. There is even the possibility that the phenomenon is of germinal origin, i.e., mutation. And the analysis of a problem in which so many possible variables are apparently involved is, of course, difficult. It certainly is a challenge to all who are interested in fundamental biology.

Acknowledgments

This investigation was supported by grant CA-07487 from the National Cancer Institute, National Institutes of Health, Public Health Service.

The stock of Kappaless *Paramecium aurelia* was obtained from Dr. T. M. Sonneborn to whom I wish to express my deep appreciation.

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Manuscript received February 12, 1966.

NATIVISTIC MOVEMENTS AND MODERN NATIONALISM

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ABSTRACT. — The concept of nativism was developed originally to describe certain reactions to foreign domination, which were observed among the American Indians. It was applied later to similar developments in Oceania and other colonial areas. It was subjected to a theoretical analysis by several anthropologists and was refocused to a considerable degree. The purpose of this paper is to clarify the relationship between nativism and nationalism, which was tacitly assumed to exist but was never systematically explored, and to suggest a model for the analysis of the development of nationalism among the non-Western peoples, in which nativism, as defined in this paper, is seen as one of its important stages.

The relationship between nativism and nationalism, although implied by the very etymology of the two terms, has not been systematically explored by anthropologists or by sociologists (Barber, 1941; Turner and Killian, 1957; Smelser, 1963). Both groups have been conscious of some characteristics shared by these two types of social movements, but neither has attempted to clarify their theoretical ramifications. The main reason for this was a certain ambiguity in the interpretation of nativistic movements by anthropologists.

The concept of nativism was developed by American anthropologists to describe certain phenomena which were observed among the American Indians. It was not exposed to a theoretical analysis until the growing interest in the problems of acculturation (Herskovits, 1938) had suggested its systematic examination. This was accomplished by Linton (1943).

Linton interpreted nativistic movements as a reaction to the threat of cultural annihilation arising in "a situation of inequality between the societies in contact" (1943, p. 234). He defined a nativistic movement as "any conscious, organized attempt on the part of a society's members to revive or perpetuate selected aspects of its culture" (1943, p. 230). He also set up a typology of nativistic movements by dividing them into the following four categories: revivalistic-magical, revivalistic-rational, perpetuative-magical, and perpetuative-rational.

Although he cited some examples of at least three of these categories, he put such an emphasis on the revivalistic- magical type that the very concept of nativistic movements became identified with what he described as "frankly irrational flights from reality" (1943, p. 233).

The criticisms of Linton's conception were slow in coming, but since 1956 it has been under attack from two main points of view: (1) the validity of setting up "nativistic

movements'' as a distinct category of phenomena, and (2) the validity of his interpretation of such movements as irrational flights from the present into the past.

The very existence of nativistic movements as an independent and separate category was questioned by Wallace (1956), for whom they constitute rather a relatively indistinct subclass within a broader category of revitalization movements. These are defined as ''deliberate, conscious effort[s] by members of a society to construct a more satisfying culture'' (1956, p. 265).

Nativistic movements are simply revitalization movements in which there is a strong emphasis on the elimination of alien influences and persons from the life of a given society. ''Because a major part of the program of many revitalization movements'', explains the author, ''has been been to expel the persons or customs of foreign invaders or overlords, they have been widely called 'nativistic movements'. However, the amount of nativistic activity in movements is variable. . . . Nativism is a dimension of variation rather than an elemental property of revitalization movements'' (1956, p. 278).

Other criticisms advanced against Linton's views questioned his interpretation of nativistic phenomena as largely regressive and irrational.

The first serious challenge came from Voget (1956) who pointed out that certain patterns of revivalistic nativism, when seen against the background of passive resistance to acculturation, represent actually a dynamic and creative reaction to the changed conditions of life. Thus, besides the passive and the dynamic types of nativism, it is possible to distinguish also a reformative type which can be defined as ''a relatively conscious attempt on the part of a subordinated group to attain a personal and social reintegration through a selective rejection, modification, and synthesis of both traditional and alien (dominant) cultural components'' (1956, p. 250).

The position taken by Voget was anticipated by the writings of some other anthropologists (Redfield, 1953), but he set it forth much more clearly and explicitly.

The second, even more serious, challenge to Linton's interpretation came from Worsley (1957). ''While the actions taken in the magical type of movements'', observes the author, ''are ineffective as a means of effecting changes in the environment, nevertheless they represent attempts to solve real problems. . . . The people set themselves real tasks, though instead of changing the environment, they only effect changes in their own psyches. In relation to the knowledge and techniques at the disposal of the people, these actions are clearly not irrational . . .'' (1957, p. 26-27).

The traditional content of the movements should by no means be exaggerated. ''There are examples'', says the author, ''in all millenarian movements of the revival of old ideas with a totally new significance in the changed social setting. . . . In addition, one finds new ideas which are not part of the traditional corpus of beliefs and knowledge. . . . What is really important about *re*adoption of *certain* of the old customs is not so much their revival, as the positive

break with European ideology that itself replaced the ancient beliefs''. To describe all millenarian movements as ''nativistic'' in Linton's meaning of the term, is actually to caricature them. There is really little that divides some such movements from ''ordinary nationalist movements'' (1957, p. 21, 24, 30).

This last observation of Worsley reiterates the views of several other students of nativism in Oceania (van der Kroef, 1946; Allen, 1951; Guiart, 1951, 1956; Keesing, 1946; Oliver, 1952) and brings us back to the problem of the relationship between nativism and modern nationalism. This relationship has been taken for granted by such anthropologists as Linton (1943), Krober (1948), or Gillin (1948), but its theoretical implications were somehow ignored. The only attempt to reinterpret the meaning of nativism from the point of view of continuity between the two was that of Honigmann (1959), who defined it broadly as ''any social movement arising under culture contact in which members of a community assert cultural or social identity, affirm dominance, or effect psychological readjustment'' (1959, p. 262).

This definition as well as some of Honigmann's references to the specific movements bring nativism so close to nationalism that the distinction between the two is by no means clear. Before we consider this problem, however, let us summarize the main elements of current anthropological views on nativism:

1) movements traditionally, and loosely, labelled 'nativistic' are essentially movements of cultural reconstruction or revitalization, their varying degree of nativistic coloring is not their distinctive characteristic;
2) they are not to be interpreted as instances of irrational flights from reality, but as attempts, however inadequate, to cope with it;
3) they are not exclusively, or even predominantly, regressive, but represent always some form of synthesis between the old and the new;
4) they are not peculiar to the non-literate societies, but may appear in any society experiencing a profound threat to its way of life;
5) they are not a separate class of social movements, but rather a primitive counterpart of modern revolutionary movements, such as socialism, communism or nationalism.

In view of these conclusions, further use of the term 'nativistic movements' to describe the broad category of social movements caused by the catastrophic impact of culture contact, does not seem to be justified. It ought to be limited to those of them which contain, as Wallace puts it, ''strong emphasis on the elimination of alien persons, customs, values and/or materiel from the mazeway'' (Wallace, 1956, p. 267).

Such movements, however, have a distinct affinity to nationalism and, in fact, seem to represent one of its primitive forms. This has not been generally recognized because such primitive manifestations of nationalism are limited to the developing countries and in this area the very definition of nationalism is still an open question.

To some students of the developing countries, for example, Hodgkin (1956), it is justifiable to apply the terms ''nationalist'' and ''nationalism'' to any and all groups which explicitly assert the rights and aspirations of a given native society in opposition to European authority, no matter what their institutional forms

and objectives. This would naturally include nativistic movements as well.

To others, for example, Coleman (1963), a basic distinction must be drawn between the "modern nationalism" and the "traditional nationalism". The latter category would include: movements of resistance to the initial penetration and occupation, early revolts provoked by political and economic oppression, and nativistic or messianic movements. The category of modern nationalism would include: sentiments, activities, and organizational developments aimed explicitly at the self-government and independence of a given country as nation-state.

This delimitation of what is to be considered as modern nationalism is quite satisfactory, but the extension of the same term, even with a qualifying adjective, to the pre-nationalist forms of resistance, is rather confusing.

Thus, the most logical seems to be the third approach represented, for example, by Emerson (1960), which would definitely restrict the use of the term to the political movements aiming at the self-government and led by the Westernized urban elite with a certain degree of modern supra-tribal identification.

Emerson pays very little attention, however, to various forms of the pre-nationalist protest. His Hegelian three-stage scheme of the development of nationalism among the non-Western peoples: (1) a xenophobic defense of the existing order, (2) an uncritical self-humiliation and acceptance of alien superiority, and (3) a nationalist synthesis, is, perhaps, like an earlier similar one by Elkin (1936/1937), too sweeping. I would like, therefore, to propose a somewhat broader model for the analysis of the typical process of development by breaking it up into at least four phases:

1) *the phase of xenophobic defense of the old order*—this would include initial resistance and later revolts;
2) *the phase of resignation, passive submission, and self-abasement;*
3) *the phase of the pre-nationalist protest immediately preceding the development of true nationalism and leading to a gradual redefinition of the group's self-conception* — this would include such phenomena as messianic and millenarian movements (if these involve a strong anti-alien sentiment), separatist churches, and varied forms of civil disobedience (riots, boycotts, non-cooperation, etc.);
4) *the phase of genuine nationalism.*

Within this theoretical model, the term nativism could, then, be logically applied to all the phenomena of pre-nationalist protest and resistance, preceding immediately the development of genuine modern nationalism. *The implication here is that a nativist reaction, especially in the form of nativistic movements* (in the revised meaning of the term), *is one of the important components in the development of nationalism, but not that nativist reaction or movements must inevitably and necessarily lead to nationalism.* There are too many intervening variables to be considered in each specific case. It is significant, however, that even in the case of classical "nativistic movements", that is, those observed among the American Indians, it was pointed out that some of their forms have provided an "affect-base" upon which "a nationalistic Pan-Indianism seems now to be emerging". (Voget, 1956, p. 259).

I submit that such a redefinition of the original meaning of the term

"nativistic movements", following Wallace's interpretation, but extending it beyond the limits of the tribal society *sensu stricto,* would contribute to the clarification of some knotty problems involved in the study and definition of modern nationalism.

When set up against this variable background of nativist unrest, the genuine nationalism may be perceived more clearly as a phenomenon representing a somewhat more advanced level of social development and may be defined in its essentials as "the active solidarity of a group claiming to be a nation and aspiring to be a state" (Symmons, 1965, p. 227).

Acknowledgments

This paper was presented, in its original form, at the Annual Meeting of the Central States Anthropological Society in May, 1964.

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Manuscript received February 17, 1966.

MIDWESTERN DENDROCHRONOLOGY AND ARCHAEOLOGICAL DATING

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Abstract. — Although one attempt has been made to date a midwestern archaeological site by dendrochronology the dates obtained have been distrusted and the technique neglected by midwestern archaeologists. However, evidence derived from independent experimentation with dendrochronolgy and from a reevaluation of the archaeological materials from the site with the disputed dendrochronological dates suggest that the technique and the dates may well be valid.

Dendrochronology, or dating by tree-ring analysis, was first undertaken in the midwest by Florence Hawley (1941) who developed generalized master-charts for pine and oak-ash extending back to A.D. 1675 and A.D. 1536 respectively. Of greater archaeological significance however were the investigations made by Robert E. Bell (1951, 1952) who utilized red cedar (*Juniperus virginiana*), a rather slow-growing tree which was heavily utilized at the aboriginal Kincaid site in southern Illinois. A master-chart extending from A.D. 1943 to A.D. 1120 was developed for this species from specimens collected from southern Illinois, northwestern Kentucky and southeastern Missouri, and using this master-chart dendrochronological dates from about A.D. 1500 to 1600 were obtained from archaeological tree-ring specimens from Kincaid. Because radiocarbon dates, which were obtained from *supposedly* related sites, were much earlier than these tree-ring dates, midwestern dendrochronology was relegated to a position of disrepute. No attempt has been made to apply dendrochronology to a midwestern archaeological site since the publication of Bell's work.

There are data to suggest however that the midwestern archaeologist's disillusion with dendrochronology was (and is) ill-founded. In support of midwestern dendrochronology two arguments, based on (1) the independent collection and analysis of a number of tree-ring specimens from central Illinois and (2) a closer scrutiny of the archaeological data (other than dendrochronological data) from the Kincaid site (as presented in Cole et al., 1951) to determine the site's probable chronological position, are presented here.

Tree-Ring Analysis in Central Illinois

A total of fifty-two tree-ring specimens were obtained from the counties of Ful-

ton, Mason, Cass and Schuyler in central Illinois, forty-three of these being red cedar and the remainder being other coniferous species. Twenty-four samples were collected by the use of an increment bore on living trees and twenty-eight more or less complete cross-sections were obtained from fence-posts, logs, stumps and living trees.

The difficulties involved in working with the junipers, because of the numerous double or false rings, missing rings and distortion due to lobing, are well known, and this difficulty was multiplied by the necessity of dealing in large part with cores rather than complete cross-sections. Other difficulties arose in building the master-chart and cross-dating specimens with it because of the necessity (due to the lack of adequate measuring equipment) of using skeleton or short plots where only the narrow or "sensitive" rings (as compared to those immediately adjacent) are considered rather than histograms where actual measurements are made of all rings (cf. Bell, 1952, pp. 349-350). However, some satisfactory results were obtained.

A large percentage of the specimens collected were sensitive, particularly those from trees growing on the tops and sides of well drained loess bluffs and clay hills, and many specimens agreed well with one another (Fig. 1). By utilizing a number of red cedar specimens which were most in agreement a short master-chart was built up. In regard to this master-chart it must be remembered that a master-chart is a composite or average of many specimens and no individual specimen, nor even all radii of a single specimen, will necessarily agree perfectly, although the majority of the rings, particularly those that are consistently narrow, must be in agreement for the specimen to be cross-datable.

The ultimate test, and utility, of any dendrochronological series is whether or not specimens with unknown cutting or dying dates will cross-date with it. Specimens of this type were collected from stumps, logs and fence-posts, plotted, and compared with the master-chart. Satisfactory cross-datings were obtained in a number of cases (e.g. Fig. 1, specimens F-36 and F-42).

Despite the fact that the data collected from central Illinois have only resulted in a very short master-chart (slightly over one hundred years) the important implication is that with in-

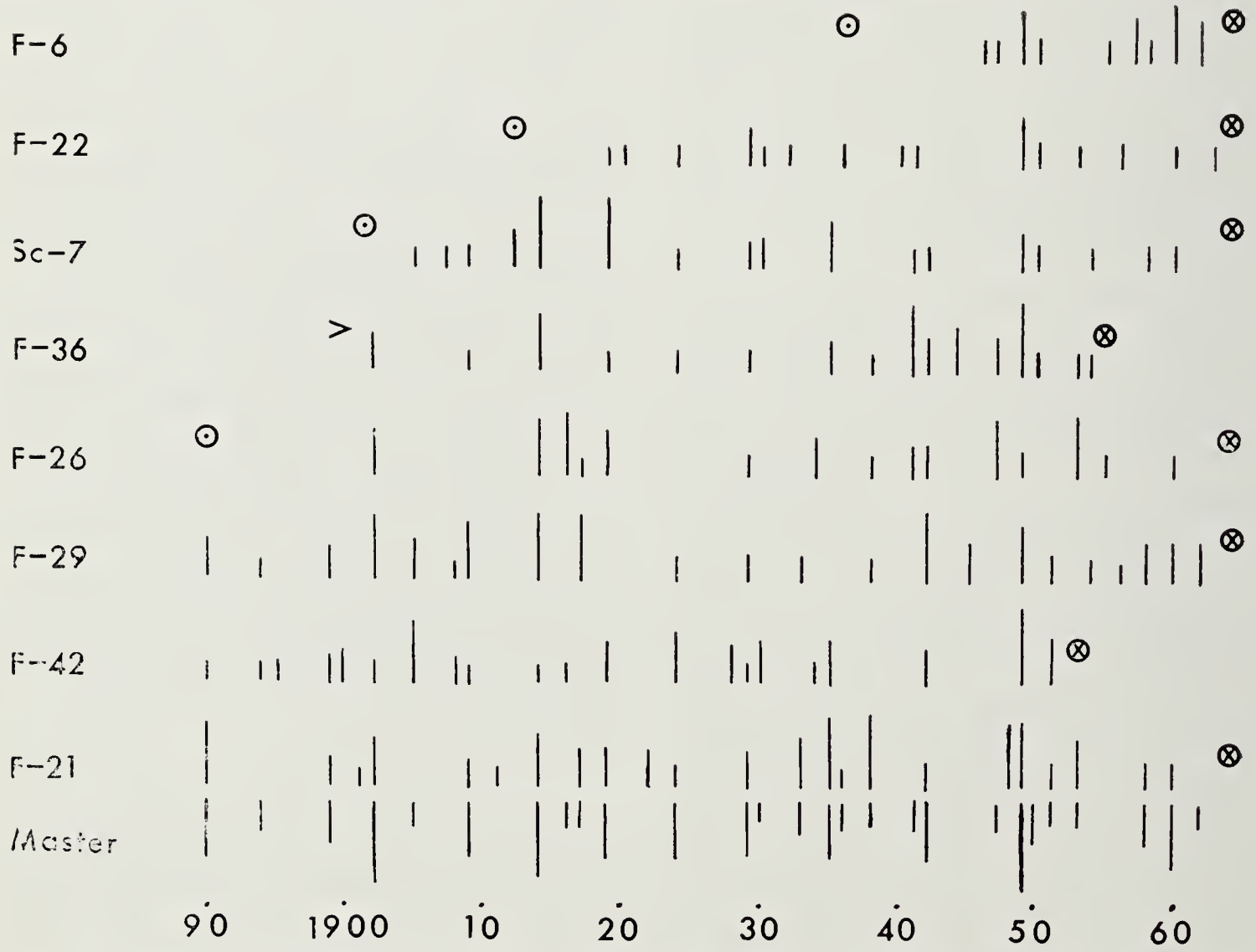

Figure 1. — Skeleton or short plots of the ring patterns of individual red cedar specimens from central Illinois compared to the central Illinois master-chart.

dependently derived data a master-chart has been constructed and it is possible to cross-date specimens with it.

Parenthetically, when the master-charts for central Illinois (Fig. 1) and southern Illinois (Bell, 1951, fig. 7) are compared it is obvious that although a number of rings agree there are far too many differences to make it possible to use the "Kincaid series" for central Illinois specimens. It is not at all surprising that this difference exists because the southern part of the state lies at the northern edge of the subtropical climatic zone whereas central Illinois is well within the temperate zone, the two areas thus having rather substantial climatic differences.

The Dating of the Kincaid Site

The difficulties that have surrounded the acceptance of the dendrochronological dates for the Kincaid site may be attributed in large part to several assumptions made in the archaeological interpretation of the site. Kenneth G. Orr (1951), working with ceramic materials from mounds Mx°4, Mx^{v}1A-35, Mx^{v}1A-41 and Mx^{v}1B, divided the Mississippian occupation of the site into three periods. Using trade materials these periods were then aligned with other Mississippian complexes in the eastern United States; the Early period supposedly being temporally equivalent to Cahokia Old Village and the Hiwassee Island focus, the Middle period equaling the Dallas focus, and the Late period equating with Cahokia Trappist and the Mouse Creek focus (cf. Cole et al., 1951, fig. 48).

The dendrochronological dates, with one exception, were obtained from only one of these mounds, Mx°4, and the dates of the individual samples agreed with their relative positions in the mound; that is, the earliest dates are at the lowest levels. The lowest sample from the mound dated A.D. 1523 and the highest A.D. 1598. A date of A.D. 1613 was obtained from an additional sample from Mx^{v}1C. Laboring under a telescoped, pre-carbon 14 concept of time-depth, the assumption was then made that this ninety year span, A.D. 1523 to 1613, encompassed more or less the entire Mississippian occupation of the site. With the "insistence" that Early Kincaid, dated A.D. 1523 by dendrochronological methods, was temporally equivalent to Old Village, the first radiocarbon dates for Cahokia (12th century A.D.) seemingly collapsed virtually all faith in midwestern dendrochronology. How, then, can these two apparently contradictory bodies of data be reconciled?

First, one very significant factor seems to have been overlooked in the scuttling of the Kincaid dates; there is a considerable amount of material from the site which almost undeniably dates to the protohistoric or even historic period: for example, Madisonville focus and Natchez sherds. With this point in mind, and in an attempt to reconcile a date of A.D. 1523 with a component which has been equated with Cahokia Old Village, two hypotheses will be explored. 1) The site is indeed contemporary, in part, with at least a portion of what has been called Old Village, but the occupation persisted until the mid-17th century and the dendrochronological dates (and, necessarily, Mx°4 from which they were obtained) pertain only to the latter occupation. 2) There is no "Early" Mississippian occupation at the site; the materials attributed to this period have been mis-identified and actually are representative of late Middle and Late Mississippian periods.

The crux of both considerations is mound Mx°4, from which the bulk of the dates were obtained, and its chronological position in the site. Orr (1951, p. 297) refers to it as a "Domiciliary . . . (mound) . . . built up by the superposition of one house floor upon the other . . . ." (i.e. an accretion mound) and this is further implied by the statement (p. 305) that "Differences in depth of deposits suggested that the four mounds of the combined sample represented time periods of differing duration." Fay-Cooper Cole, et al (1951, p. 58), however, are explicit in stating that it is ". . . a low truncated pyramid with steeply sloping sides." Assuming that it is a truncated pyramid mound (and Cole's figure 10 illustrates rather conclusively that it is) might it be the case that its building stages *do not* correspond to all periods of the Mississippian occupation but rather that the mound was built in a relatively short period of time during the latter portion of the occupation and the "early" materials in the fill had been scraped up from the adjacent village area? Unfortunately the bulk of the materials from Mx°4 are not discussed as a unit but rather have been lumped (in presentation) with the three

other mounds involved, and it is therefore impossible (without re-examining the material) to determine the quantity of "late" materials from the lower levels, which, if they exist, should substantially strengthen this argument.

However, one good argument for a late date for mound Mx°4 is the occurrence in its middle levels of sherds with wide-line guilloche designs. In regard to these sherds James B. Griffin (quoted in Cole et al., 1951, p. 149) states, "Broad line curvilinear and rectilinear incising featuring the guilloche designs is certainly connected with the similar style in the Madisonville focus." At the Madisonville focus type-site in Ohio typical sherds and vessels of Madisonville types were found in definite association with historic trade materials (brass and iron objects, glass beads). Griffin (1943, p. 308) suggested a terminal date of A.D. 1670 to 1690 for this complex and this date was substantiated by James A. Brown (1961) when he demonstrated that at the Zimmerman site in northern Illinois the historic Danner complex, identified as Shawnee and well-dated at A.D. 1684 to 1688, had Madisonville pottery types. In addition a radiocarbon date of A.D. 1480 ± 150 (M-831) for Early Madisonville nicely brackets the Kincaid dendrochronological dates.

Turning to the hypothesis that the entire Mississippian occupation of the site is late, we find a number of relevant factors. Cordmarked bowls more or less analogous to Cahokia Cordmarked were found in the Early levels (Orr, 1951, p. 354) and Cahokia Cordmarked, although undeniably beginning at an earlier date, has been dated by radiocarbon techniques as late as A.D. 1435 ± 100 (M-1332) and A.D. 1565 ± 90 (M-1334) at Cahokia. Also in regard to Cahokia relationships, many of the Kincaid "Old Village" types don't look particularly like Cahokia Old Village types; the specimen in Orr's (1951) plate 27 *b* appears to be engraved and plate 27 *k-l* are similar to what most Cahokia archaeologists would call "Mound Place-like."

Furthermore, some Moundville-like sherds are present at the site and one incised specimen from Early Kincaid (Orr, 1951, p. 354, Plate 26B *i*) is similar to the type Moundville Incised. Concerning this type Douglas H. McKenzie states, "The similarity to proto-historic and historic types may indicate that Moundville Incised occurred late in . . . (the A.D. 1250 to 1500) . . . time span." (1965, p. 62). It is also noteworthy that negative painted bottles with swastika designs (a Southern Cult motif) apparently occur in all levels (Orr, 1951, p. 334). Also, Plaquemine sherds were found in the Middle levels (ibid., p. 354), Plaquemine having been dated by radiocarbon as late as A.D. 1600 ± 250 (M-30), and one sherd of Fatherland Incised, a historic Natchez type dating A.D. 1650 (?) to 1730, was found in a Late period context (Cole et al., 1951, p. 152).

Further confirmation of the late alignment comes from the Mississippian Tinsley Hill focus centered about thirty miles south of Kincaid in the Tennessee-Cumberland region of Kentucky. In regard to the relationship of this cultural complex and Kincaid it is stated that ". . . the Kincaid Focus . . . (is) . . . a late manifestation culturally and temporally comparable to the Tinsley Hill ceramic complexes . . . ." (Clay, 1963, p. 142), and three radiocarbon dates obtained for Tinsley Hill focus sites are A.D. 1540 ± 80 (I-479), A.D. 1600 ± 85 (I-477) and A.D. 1650 ± 80 (I-478).

However, a single radiocarbon date from Kincaid of A.D. 1275 ± 150 (M-888) has been obtained from a ". . . log tomb associated with the surface of the earliest of the three mound stages . . . ." in mound Pp°2 (Crane and Griffin, 1960, p. 35). Although this date is somewhat difficult to evaluate because of the paucity of associated artifacts it does suggest that the Mississippian occupation of Kincaid *began* prior to A.D. 1500.

Summary and Conclusions

Since the use of radiocarbon dating, which appeared to negate the midwestern dates previously obtained by dendrochronology, dendrochronology has been scorned by the majority of midwestern archaeologists. However, recent independent experimentation with dendrochronology in central Illinois has resulted in a workable (although short) master-chart, and there is considerable archaeological evidence from the one midwestern site dated by dendrochronology to suggest that the site was occupied during the period indicated by the dendrochronological dates. For these reasons it is argued

that dendrochronology should be reinstated to a position of respectability as a valid and applicable method of dating in the midwest.

Unfortunately it will be difficult in many areas to develop master-charts of adequate length for archaeological dating. However, Bell's master-chart, which extends to A.D. 1120 and was constructed primarily from specimens obtained from about thirty miles south of St. Louis in Jefferson county, Missouri, should be usable for archaeological red cedar specimens from the Cahokia site near East St. Louis, as well as for specimens from sites in southern Illinois, northwestern Kentucky, the Missouri "Boot-Heel" and for an undetermined distance up the Tennessee, Cumberland and Ohio Rivers. Since dendrochronology provides absolute dating of a precision impossible to attain by radiocarbon dating, special efforts should be made to collect and preserve dendrochronology specimens from archaeological sites in these areas.

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Manuscript received January 15, 1966.

AVOIDANCE OF STAINING ARTIFACTS IN SMEARS OF ECTOTHERM BLOOD

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ABSTRACT. — The destructive effect of unsuspected water contamination in Wright's stain upon the morphology of the blood cells of certain ectotherms was studied. The results agree with those found in mammals. In the frog, the cytoplasm of the red and of some of the white cells became vacuolated and the red cells tended to show changes in shape. In the turtle, similar vacuolization of cells occurred, with no changes in shape of the red or white cells. In *Necturus* there was a tendency toward vacuolization in red and white cells, but no changes in cellular size or shape. Experimental addition of 1 ml of water to the stain produced crenation and marked cytoplasmic vacuolization in the red and white cells of the frog. The vacuolization effects were essentially similar although less marked in *Necturus* and the turtle, but there were no changes in the size or shape of the blood cells. Prior treatment of blood smears in 95 percent methanol reduced all artifacts in the frog and turtle. The optimal treatment for *Necturus* involved drawing blood into 1 percent acetic acid, smearing the blood on slides and then immersing the smear in 95 percent methanol prior to staining.

It has been shown in the human peripheral blood smear that Wright's stain may produce artifacts affecting primarily the red blood cell (Bettigole, 1964). Because of the increasing use of amphibians and reptiles in research, it is of interest to find whether their blood cells, both red and white, are similarly affected by the procedure used to visualize them and, if so, to establish remedial measures. Three common laboratory ectotherms were selected for this purpose, a salamander, frog and turtle.

MATERIALS AND METHODS

Frog and turtle. Blood of *Rana pipiens* and *Pseudemys scripta elegans* was obtained by cardiac puncture in a syringe containing 1.6 percent sodium oxalate, using 1 volume of anticoagulant to 9 volumes of blood (Kaplan, 1956). When heparin was used, it produced a slight tendency toward shrinkage of the red cells in the frog, but not in the turtle. Blood smears were made on slides and stained with Wright's stain.

Commercial Wright's stain is frequently contaminated with traces of water, especially upon standing, and the effect of this contaminant was studied. A number of Coplin jars were filled with 50 ml of Wright's stain. Water was added in specific amounts such that a graded series of two or three solution concentrations was obtained. The differential effect of water contamination could then be visualized. Some jars were filled with commercially obtained Wright's stain with no extraneous increments of water experimentally added.

To test the possible protective effect of prior fixation in alcohol against artifact formation, some slides were fixed for periods varying from 10 seconds to 8 minutes in 95 percent methyl alcohol before staining for 3 to 6 minutes in undiluted commercial Wright's stain. They were rinsed for 1 minute in distilled water for its acidic reaction, then for 1 minute in tap water for its basic reaction and finally dried in air. Other slides were also fixed in methyl alcohol, but they were then immersed in Wright's stain containing varying amounts of added water.

Salamander. It was found on blood obtained by cardiac puncture from *Necturus m. maculosus* that the cells drawn into 1.6 percent sodium oxalate, 3.4 percent sodium citrate or 1 percent heparin tended to be distorted. Heparin produced shrinkage. The oxalate or the citrate used in 1 to 9 volume ratios in isomolar concentrations did not fully prevent coagulation. Therefore, the blood was drawn into 1 percent glacial acetic acid in the ratio of 0.1-0.3 ml of acetic acid to each ml of blood and then smeared at once. Tobias (1936) reported that acetic acid expands red cells. We have observed that it minimizes any shrinkage due to later treatment by other chemicals.

Results

Some typical results are illustrated in Figure 1. The presence of red cell staining artifacts due to water spontaneously occurring in commercially obtained Wright's stain produced cellular changes. In the frog the red cells were found to be prominently vacuolated, with many cells showing a minor tendency to change their shapes. Some of the white cells of the frog also became vacuolated. If the smeared slides are not rapidly dried prior to staining by waving them to and fro in the air, vacuolization of all the blood cells can be artificially produced to a greater or lesser degree.

In the turtle blood which was stained with commercial Wright's stain, the red cells were commonly vacuolated somewhat in excess of the normal, but their shape and size did not appear to be changed. All the turtle white cells showed many vacuoles which coalesced and distorted the normal cytoplasmic architecture.

In *Necturus* blood which was stained with commercial Wright's stain there was the least vacuolization of the three animal bloods examined, although the abnormality was definite. There was no obvious alteration of the shape or size of the red cell. The white cells failed to stain as prominently as they did in water-free stain.

Two or three drops of water added to 50 ml of stain in the Coplin jar produced red and white cell vacuolization in the frog and turtle, the effects being clearly greater than that seen with the undiluted commercial Wright's stain. If the staining solution stood for several days, the aberrations were even more obvious. There was also greater vacuolization in the *Necturus* red cells but the white cells showed no greater changes than those seen in the undiluted commercial Wright's stain. The frog red cells showed a crenation that did not appear in *Necturus* or turtle red cells.

In frog blood 1 ml or even less of water added to 50 ml of Wright's stain produced more marked distortion than a single drop did. There were severe red cell crenation and considerable cytoplasmic vacuolization of both red and white cells. All these effects worsened with increasing dilution. When the frog smears were immersed in diluted Wright's stain that had been standing

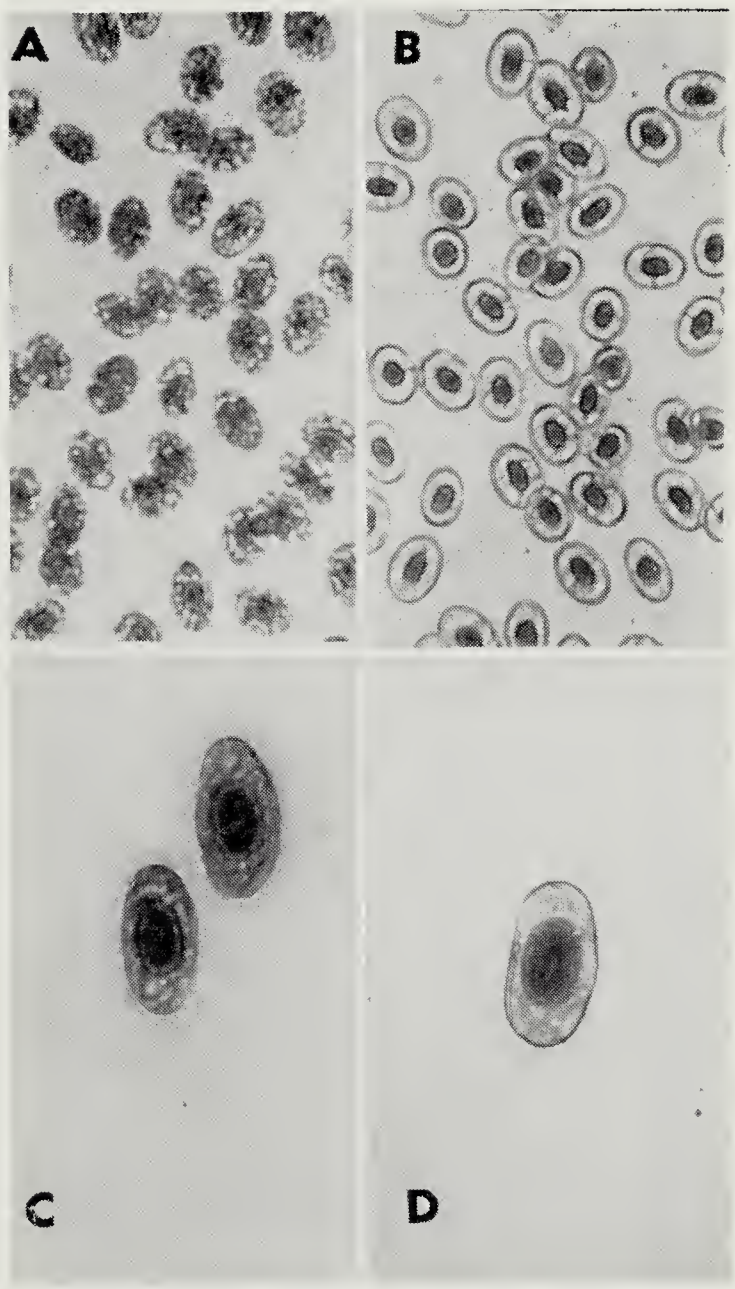

Figure 1. A. Red cells of frog stained in Wright's stain to which 1 drop of water was added. x 965. B. Red cells of frog treated in methanol prior to staining. x 1,020. C. Red cells of *Necturus* stained in Wright's stain to which 1 drop of water was added. x 1,075. D. Red cells of *Necturus* drawn into acetic acid, smeared and immersed in methanol prior to staining. x 1,200.

several hours, the deleterious effect upon the cells was even more severe.

In turtle and *Necturus* blood addition of 1 ml of water to 50 ml of Wright's stain produced greater vacuolization of cells than that seen in undiluted commercial Wright's stain. The shape and size of the red cells were not affected. The white cells of both animals were vacuolated.

The drawn blood of the three test animals was then treated to try to eliminate any of the effects of water dilution upon the final appearance of the stained cells. The optimal treatment for the frog was found to involve immersion of dried smears of oxalated cardiac blood in 95 percent methanol for at least 2 minutes, in commercial Wright's stain for 3 minutes, in distilled water for 1 minute, and in tap water for 1 minute. Crenation and cytoplasmic changes were prevented. The white cells were readily differentiated and their cytoplasmic morphology was normal.

The optimal treatment for the turtle involved immersion of dried smears of oxalated cardiac blood in 95 percent methanol for about 2 minutes, in commercial Wright's stain for 6 minutes, in distilled water for 1 minute and in tap water for 1 minute.

The optimal treatment for *Necturus* involved drawing blood by cardiac puncture into a syringe containing 1 percent acetic acid (0.1-0.3 ml of acid/ml of blood), smearing this blood quickly, and immersing the smear in 95 percent methanol for 15-30 seconds, in commercial Wright's stain for 3 minutes, in distilled water for 1 minute and in tap water for 1 minute. In *Necturus*, if the smear was fixed in methanol for more than 1 minute, the red cells typically took on an undesirable greenish hue.

In all instances immediate staining of freshly prepared smears produced the greatest contrast.

Discussion

If commercial Wright's stain were always completely free of water, some of the common artifacts appearing in stained smears of blood cells would be eliminated at the outset. Usually, however, the stain seems to absorb enough water upon prolonged standing to produce aberrations. The usual test of this is to put a drop of the stain upon oven-dried filter paper; if the periphery of the circular spot on the paper appears fuzzy and a pink halo arises around the blue spot, water is present.

The use of methanol prior to staining eliminates free water and produces a more uniform diffusion of the staining fluid, thus minimizing differential concentrations and perhaps variations in pH. The procedure is not new for mammals (Bell, 1950).

The data indicate that the known human blood cell sensitivity to water in Wright's stain extends down into amphibian and reptile blood. Among the ectotherms tested, the frog appears to be the most sensitive, reacting similarly to man in this regard. The cells of the turtle and *Necturus* are more resistant in that order.

The techniques used in this study are grossly qualitative, but they have been found to be reproducible among various unrelated animal colonies sampled.

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Manuscript received February 17, 1966.

HYDROLYSIS OF ADENOSINETRIPHOSPHATE BY BLUEGILL LIVER MITOCHONDRIA

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ABSTRACT. — The hydrolysis of adenosinetriphosphate (ATP) by enzymes in bluegill (*Lepomis macrochirus*) liver mitochondria shows ATP to be the primary substrate as very little hydrolysis of adenosinediphosphate (ADP) was observed. Cadmium, zinc, manganese, magnesium, and calcium ions enhanced the hydrolysis of ATP in the order given. Sodium cyanide, sodium fluoride, and iodoacetate did not affect the hydrolysis of ATP. Sodium azide and p-chloromercuribenzoate inhibited the hydrolysis of ATP, but pentachlorophenol was less inhibitory. Sodium arsenate, sodium arsenite, and dicoumarol did not affect the hydrolysis of ATP. Gramicidin and 2, 4-dinitrophenol enhanced the hydrolysis of ATP in the presence of manganese and magnesium ions.

The hydrolysis of adenosinetriphosphate (ATP) has not been extensively investigated in fish liver mitochondria systems (Tarr 1958; Gumbmann, Brown, and Tappel 1959). An increase in the hydrolysis of ATP could result in the loss of energy to the fish, as the net energy available in the form of ATP is the composite result of two general enzyme sequences, (1) the ATP-generating sequences, and (2) the ATP hydrolyzing or utilizing sequences. The energy-producing systems of bluegill liver mitochondria are being investigated as one approach to determine the effects of pollutants on aquatic organisms. This investigation was initiated to study the hydrolysis of ATP by bluegill liver mitochondria and determine if the ATP hydrolysis may be affected by possible pollutants. The term ATPase activity as used here follows the definition of ATPase as proposed by Potter (1953), namely the release of inorganic phosphate from ATP, and does not imply the existence of a single or specific enzyme or enzymes. A preliminary report of part of the present work has been presented (Hiltibran 1964), and the effect of sodium amytal and rotenone on the bluegill mitochondrial enzyme sequences has been reported (Hiltibran and Johnson 1965).

MATERIALS AND METHODS

Native, wild bluegills were maintained in aerated aquaria at 25° C. Preparations of the mitochondria and procedures for estimating the rate of release of inorganic phosphate from ATP and for determining nitrogen content of mitochondrial preparations have previously been reported (Hiltibran and Johnson 1965). The inorganic phosphate released from the ATP was converted to micromoles of phosphate per hour per milligram of tissue nitrogen. All values have been corrected for endogenous activity. The data presented are the average values from two or more experiments.

RESULTS AND DISCUSSION

Effect of Metal Ions.—Very little hydrolysis of ATP occurred in the absence of any metal ions. One micromole of cadmium, zinc, and manganese ions per

ml of reaction medium was found to promote the maximum hydrolysis of ATP. Greater or lesser quantities of these ions resulted in less ATP hydrolyzed (TABLE 1). Maximum hydrolysis of ATP occurred with a magnesium ion concentration between 1 to 5 micromoles per ml of reaction medium, but magnesium levels greater than 5 micromoles reduced the hydrolysis. The hydrolysis of ATP increased with increased levels of calcium ions up to 15 micromoles of calcium, the highest level of calcium used. Sodium and potassium ions were not effective. The values given in TABLE 1 are the average values of 25 experiments.

Zinc and cadmium ions severely inhibited oxygen uptake by bluegill liver mitochondria whereas manganese and calcium ions were less inhibitory. Also in the presence of these ions, there was a large increase in the inorganic phosphate content of the reaction medium, which was greater than in experiments in which oxygen uptake was inhibited by sodium cyanide or Antimycin A. It is now apparent that cadmium, zinc, manganese, and calcium ions were enhancing the hydrolysis of ATP, which resulted in the large increase observed in the inorganic phosphate of the reaction medium.

Effect of Substrate.—The results of preliminary experiments indicated that adenosinediphosphate (ADP) was not utilized as a substrate by the liver mitochondria in the presence of zinc, cadmium, manganese, and magnesium ions. However, in the presence of calcium ions, apparently some hydrolysis of ADP may have occurred, but this hydrolysis contributed to less than 20 percent of the total amount of the inorganic phosphate released from either ATP or ADP. These observations were confirmed in later experiments. When either ADP or inorganic phosphate was added to the reaction medium, the total amount of inorganic phosphate released was less than in the presence of ATP alone, as would be expected since ADP and inorganic phosphate are end products of the enzyme reaction. The mitochondrial enzymes did not hydrolyze sodium pyrophosphate. It appears, therefore, that the inorganic phosphate released from ATP is the terminal phosphate group of ATP and conforms to the definition of the ATPase activity as proposed by Potter (1953).

Five micromoles of ATP per ml of reaction medium did not result in a large increase in the hydrolysis of ATP over that shown by 2.5 micromoles of ATP, indicating that 2.5 micromoles of ATP were a suitable substrate level under the conditions of the experiments. Less ATP was hydrolyzed at ATP levels of 1 and of 7.5 micromoles.

Effect of Homogenizing Medium.—The ATPase activities within mitochondria prepared in various media were investigated and are summarized in TABLE 2. Water, 0.04 M sucrose, and 0.9% sodium chloride were poor homogenizing media. Active preparations were obtained from 0.15 M potassium chloride (KCl) and from 0.08 to 0.25 M sucrose solutions. The largest amounts of ATP were hyrolyzed in the presence of cadmium and zinc ions by the mitochondria prepared in 0.25 M sucrose and by the mitochondria prepared from 0.15 M sucrose when

TABLE 1.—Effects of Metal Ions on ATPase.

Ion	micromoles per ml of reaction medium	micromoles PO_4/hr/mgN
None	..	17.4
Cadmium	1	93.4
Zinc	1	69.5
Manganese	1	50.4
Magnesium	1	27.5
Calcium	5	24.3

TABLE 2.—Effects of Homogenizing Media on ATPase.

	micromoles PO_4/hr/mgN				
	Cd	Zn	Mn	Mg	Ca
KCl (0.15M)	85.9	54.9	37.4	29.9	23.4
NaCl (0.9%)	9.9	7.4	10.4	12.3	4.6
Sucrose					
0.44MS	20.2	20.1	28.1	25.7	26.8
0.34MS	12.3	9.9	31.7	24.7	18.7
0.25MS	106.6	98.8	32.7	24.3	20.0
0.15MS	83.9	83.3	49.2	24.6	18.8
0.08MS	66.7	66.2	37.4	23.7	17.3
0.04MS	7.2	11.4	13.0	7.3	4.8
Water	8.1	6.7	9.7	6.3	5.4
0.15MS +EDTA	122.4	74.5	44.7	13.7	16.9

assayed in the presence of manganese ions (TABLE 2). The sucrose concentrations from 0.08 to 0.44 M did not appreciably alter the magnesium ATPase activity. The cadmium ATPase activity was increased approximately 46 percent and the magnesium ATPase activity was inhibited about 50 percent in the mitrochondria prepared in 0.15 M sucrose containing 0.001 M ethylenediaminetetraaectic acid (EDTA). Highest calcium ATPase activity was observed in mitochondria prepared in 0.44 M sucrose.

Fractionation studies indicated that all the ATPase activity was present in the mitochondria as very little activity was found in the supernatant fractions when the mitochondria were prepared in 0.15 M sucrose.

These data indicate that the various ATPase activities were altered when mitochondria were prepared in various media. These data confirm that 0.15 M sucrose is a suitable homogenizing medium for bluegill liver mitochondria, as previously proposed (Hiltibran 1965).

Effect of Inhibitors.—The effects of several enzyme inhibitors on mitochondrial ATPase activities are summarized in TABLE 3. The levels reported are comparable to the level of the inhibitors which were utilized in the investigation of oxygen uptake by bluegill liver mitochondria in the presence of succinate (Hiltibran 1965). Sodium azide and p-chloromercuribenzoate inhibited all the ATPase activities. Cyanide, iodoacetate, and fluoride were not effective inhibitors, but fluoride was inhibitory at extremely high levels (15 micromoles).

The effects of oxidative phosphorylation uncoupling agents are summarized in TABLE 3. Arsenate, arsenite, and dicoumarol did not greatly alter any of the ATPase activities. Pentachlorophenol was somewhat inhibitory, but 2, 4-dinitrophenol (DNP) increased the hydrolysis of ATP in the presence of manganese and magnesium. Gramicidin slightly inhibited the zinc ATPase activity, but enhanced the hydrolysis of ATP in the presence of manganese and magnesium ions.

In the investigations of succinic oxidase by bluegill liver mitochondria, all the oxidative phosphorylation uncoupling agents tried except arsenate and arsenite inhibited oxygen uptake, but only arsenate, pentachlorophenol, and DNP severely altered the phosphate uptake (Hiltibran 1965). Gramicidin and dicoumarol inhibited oxygen uptake but did not greatly alter the phosphate uptake and would not be expected to affect the hydrolysis of ATP. This was confirmed. Pentachlorophenol did not alter the hyrolysis of ATP in the presence of magnesium ions and thereby must affect the synthesis of ATP.

The effect of 2,4-dinitrophenol on the succinic oxidase has been reported (Hiltibran 1965) and the

TABLE 3.—Effects of Inhibitors on ATPase.

Inhibitor	micro-moles/ml reac. med.	Ave. change in micromoles PO_4/hr/mgN				
		Cd	Zn	Mn	Mg	Ca
Azide	0.15	— 40	— 49	— 34	— 17	— 6
Cyanide	0.15	+ 2	+ 1	+ 1	+ 1	— 0.3
Fluoride	0.15	± 4	± 7	+ 3	± 3	± 1
Iodoacetate	0.15	— 1	± 3	± 19	— 1	± 5
p-Chloromercuribenzoate	0.15	— 76	— 62	— 21	— 16	— 10
Arsenate	0.15	— 10	— 9	± 3	— 7	— 8
Arsenite	0.15	— 6	— 8	— 1	— 5	— 0.5
Dicoumarol	0.15	— 30	— 7	— 11	— 9	— 5
Gramicidin	0.15[1]	— 3	— 18	+ 43	+ 14	+ 0.2
Pentachlorophenol	0.15	— 47	— 34	— 26	— 4	— 3
2,4-dinitrophenol	0.15	± 6	± 16	+ 20	+ 21	± 10

[1] micrograms.

data suggest that DNP interferes with the incorporation of inorganic phosphate into ATP. The magnesium and manganese ATPase activities were increased approximately 88 and 40 percent, respectively. DNP did not greatly alter other ATPase activities. Higher and lower levels of DNP were not particularly more effective. During the investigation of effects of various homogenizing media on the ATPase activity, the effect of DNP on the various ATPase activities was also investigated at levels of 1.5 micromoles.

The cadmium and zinc ATPase activities of mitochondria prepared in 0.25 M sucrose and 0.15 M KC1 and the magnesium and manganese ATPase activities of mitochondria prepared in 0.15 M sucrose were increased as well as were the zinc, cadmium, manganese, and magnesium ATPase activities from mitochondria prepared in 0.15 M sucrose containing 0.001 M EDTA. These data suggest that in the presence of magensium ions, the hydrolysis of ATP is increased, and thereby contributes to the uncoupling effect previously noted. Even though ATP hydrolysis in the presence of magnesium ions is increased about 80 percent, this does not appear to account for the large increase in inorganic phosphate content of the reaction medium in the investigations of succinic oxidase of mitochondria. Even though oxygen uptake was reduced about 70 percent, some incorporation of inorganic phosphate would be expected, and apparently dinitrophenol interferes with this incorporation of inorganic phosphate, and effect previously demonstrated by Eisenhardt (1964).

The importance of the cadmium, zinc, manganese, and calcium ATPases is not known. However, since these ions inhibit oxygen uptake and affect the hydrolysis of ATP, these effects on total energy production by fishes would supplement each other by decreasing energy production and promoting the energy loss. Cadmium and zinc ions are relatively toxic to fish, and these data suggest that the toxic effect of these ions might be the result of their effect on energy production.

Of all the inhibitors investigated, only the dinitrophenol effect on the magnesium ATPase activity appears to contribute to the previously reported effect on phosphate uptake. Higher levels of DNP were not any more effective, either on the magnesium ATPase, or on phosphate uptake in the presence of succinate.

Acknowledgments

The author gratefully acknowledges the technical assistance of Messrs. Lawrence Goodwin, Michael Johnson, Kenneth MacMurdo, Miss Barbara Heller, and Mrs. Marilyn Branton in this investigation.

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Manuscript received April 5, 1966.

THE GENUS *PENIOPHORA* IN ILLINOIS

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ABSTRACT.—A biogeographic and taxonomic survey of thirty-two species of the genus *Peniophora* in Illinois was made. Twenty-four of these species represent new reports for Illinois. Reference is made to Illinois locations, and to states and countries where the species have been reported to occur. A new range extension for two species, *P. subulata* and *P. argillacea*, is noted.

INTRODUCTION

Members of the genus *Peniophora* are resupinate fungi belonging to the class Basidiomycetes, sub-class Homobasidiomycetes, series Hymenomycetes, order Polyporales, and family Corticiaceae. The genus *Peniophora* was segregated from the genus *Corticium* by M. C. Cooke (1879) to accommodate some of the species that possess in the hymenium projecting, sterile, hair-like structures called cystidia. Subsequent workers developed the generic concept that all cystidiate Corticiaceae belong to the genus *Peniophora*, and that all non-cystidiate members of the family belonged to the genus *Corticium*. The author has followed this concept of *Peniophora* in order to prevent confusion, although recent investigators such as Rogers (1943), Donk (1956, 1957), Eriksson (1950, 1958), and others have segregated *Peniophora* into several genera.

Most species of *Peniophora* are common and ubiquitous. Fruiting body formation takes place on decayed coniferous and deciduous wood or bark, and less often on leaves, conifer needles and cones, other fungi, lower plants, and soil. Seemingly, this genus is important in the decomposition of the above mentioned substrates.

The species of *Peniophora* vary considerably in color, in fact so much so that little value can be attached to it for taxonomic identification. The fruiting body of *Peniophora* is resupinate. It lies flat on the substrate, and in some species is somewhat reflexed at the margins. It may be widely effused or occur in small patches which may or may not coalesce. The surface of the fructification varies in appearance from smooth to tooth-like. It may be continuous or discontinuous, and with or without fissures. The margin usually exhibits a radial pattern of mycelial growth, often with occasional rhizomorphs, and may thin out, end abruptly, or reflex. The fungal body usually consists of three distinct layers, the hymenium, subhymenium, and subiculum. The hymenium is at the surface of the fungal body and is composed of structures of great importance in the identification of species. These structures are the basidia, cystidia, gloeocystidia, and cystidioles, with the lat-

ter two being absent in many of the species of *Peniophora*. Also of much taxonomic importance are the basidiospores that are borne on the sterigmata of the basidia.

The inconspicuous nature of this genus and the difficulties involved in studying the group have discouraged many investigators. Prior to this study, only eight species had been reported for Illinois. Collections made by the author, along with collections made by D. P. Rogers and A. E. Liberta, have contributed 24 additional species of *Peniophora* previously unreported for this State.

Methods

All descriptions of the 32 species of *Peniophora* in Illinois are based on Illinois material either collected by the author, or housed in the Farlow Herbarium, the Illinois State University Herbarium, or the personal herbarium of A. E. Liberta. These herbaria are abbreviated (RJH), (FH), (ISU), and (AEL) respectively. All measurements and microscopic descriptions were made with the compound light microscope at X1000. Microscopic details were taken from observations made with the dissecting microscope at X24.5. All microscopic preparations were made according to the procedure described by Slysh (1960). Colors of the fructifications that were matched with Maerz and Paul's *Dictionary of Color* (1950) have their first letters capitalized, and the location of the matching color is indicated in parenthesis following the color title. For example, Grey Stone (13A2) would mean that this color may be found in the *Dictionary of Color* on plate 13, column A, row 2. The majority of descriptive terms used can be found in Snell and Dick's *Glossary of Mycology* (1957). The abbreviation "Syn." indicates that all binomials here are synonymous with the species being described. Reference is also made to states and countries where the species have been reported to occur. The term "rare" indicates that the species was collected in only one region of Illinois, and the term "common" was applied to species collected in more than one area of the state.

A dichotomous key was constructed from the descriptions of all 32 species. The number before each species indicates the number of the descriptive paragraph and figure.

Figures were drawn from the Illinois material with the aid of a camera-lucida at X1000. A 10 micron scale has been drawn to indicate the relative size of the structures in the figures. One 10 micron scale per plate indicates that all figures on the plate pertain to that scale. When this is not the case, a scale is provided for each figure.

Key to the Species

1. Cystidial walls dissolving in 10% KOH 2
1. Cystidial walls not dissolving in 10% KOH 6
   2. Cystidia with a definite apical bulb; spores ellipsoid to broad-ellipsoid, (3-)3.5-5.5 x 2-3(-3.75)μ .....1. *P. accedens*
   2. Cystidia without a definite apical bulb; apex sometimes wider than stem, but not bulbous 3
3. Cystidial apex lance-like; stem narrowly conic; spores narrowly clyindric, (6-)6.5-8(-9) x 1.5-2(-2.5)μ .. ..2. *P. subulata*
3. Cystidial apex not lance-like, but either tubular or hooded 4
   4. Cystidial apex tubular, and not distinctly hooded; capillary lumen widening abruptly; spores cylindrical to suballantoid, (6.5-) 7-9.5 x 1.5-2.2μ ..3. *P. gracillima*
   4. Cystidial apex slightly to prominently hooded 5
5. Cystidial apex only slightly hooded; spores cylindrical, and somewhat curved at apiculus end, 5-6.5(-7) x 2-2.5(-2.7)μ .....4. *P. pirina*
5. Cystidial apex prominently hooded; spores cylindrical, and often somewhat curved at apiculus end, (4.5-) 5-7(-7.5) x (1.5-)2-2.5(-3)μ ....5. *P. calothrix*
   6. Spores echinulate, even in KOH, nonamyloid, 6-9 x 4.5-7.5μ ....6. *P. praeterita*
   6. Spores smooth 7
7. Cystidia septate 8
7. Cystidia nonseptate 12
   8. Cystidia of two general types: one cylindrical-capitate and unincrusted, the other acicular to subulate and incrusted; spores mainly oval, 3.5-6 x 2.5-3.5(-4)μ ....7. *P. pallidula*
   8. Cystidia of one type 9

9. Cystidia incrusted with large, coarse crystals 10
9. Cystidia finely incrusted or unincrusted 11
    10. Hymenium light colored, cream to greyish-white, and minutely odontoid; cystidia 6-12μ wide; spores oblong-ellipsoid, 7.5-11.5 (-12) x 3-4.5μ .....8. *P. aspera*
    10. Hymenium dark colored, tanish, and hirsute; cystidia (7-)9-13μ wide; spores cylindrical to oblong-ellipsoid, (6.5-)8.5-11(-12) x 3.5-4.5μ ....32. *P. subtestacea*
11. Cystidia finely incrusted with hair-like crystals or unincrusted, and 3.5-5.5μ wide; spores broadly ellipsoid, 4-5(-6) x 2-3μ ..9. *P. byssoides*
11. Cystidia delicately incrusted with granular crystals or unincrusted, (6-)7-9.5μ wide; spores oblong-ellipsoid to sub-ovate, 6-8(-9.5) x (3.5-)4-5μ .....31. *P. polonensis*
    12. Gloeocystidia present 13
    12. Gloeocystidia absent 19
13. Cystidia heavily incrusted 14
13. Cystidia mainly unincrusted and varying in shape; spores oblong-ellipsoid, 7.5-10(-12) x (3.5-)4-6μ ... .10. *P. tenuis*
    14. Majority of cystidia over 60μ long 15
    14. Cystidia measuring under 60μ long 16
15. Cystidia 8.5-18μ wide; gloeocystidia rare; spores oblong-ellipsoid, 7.5-9.5 x 3.5-4.5μ .....11. *P. pubera*
15. Cystidia 8-12(-15)μ wide; gloeocystidia frequent; spores cylindrical, (9-)10-16.5 x (3-)3.5-4.5μ ....12. *P. mutata*
    16. Gloeocystidia large, with the majority ranging from 40-125μ in length 17
    16. Gloeocystidia smaller, with the majority under 40μ in length 18
17. Gloeocystidia up to 10μ wide; spores cylindrical, 9.5-15 x 3.5-4.5μ ....13. *P. heterocystidia*
17. Gloeocystidia up to 15μ wide; spores broadly cylindric to oblong-ellipsoid, 7-10(-12) x 2.5-4(-5)μ ....14. *P. incarnata*
    18. Gloeocystidia numerous, broadly obpyriform, up to 20μ wide; spores suballantoid, 7-9 x 2-3μ .....15. *P. nuda*
    18. Gloeocystidia rare, clavate, up to 10μ wide; spores cylindrical to suballantoid, 7-9(-10) x 2.5-3.5μ .....16. *P. violaceo-livida*
19. Majority of cystidia heavily incrusted 20
19. Cystidia unincrusted or sparsely incrusted 26
    20. Hymenial surface turning wine-red with the application of 3% KOH; spores ovoid to ellipsoid, (15-)20-25(-29) x 4-5(-6)μ ....17. *P. filamentosa*
    20. Hymenial surface not turning wine-red with the application of 3% KOH 21
21. Hyphae simple-septate, with only an occasional clamp connection in some species 22
21. Hyphae strictly nodose-septate ...24
    22. Hyphae heavily incrusted; spores broadly ellipsoid, 4.5-6.5 (-7) x (2.5-)3-4μ ....18. *P. coccineo-fulva*
    22. Hyphae unincrusted or sparingly incrusted 23
23. Fruit body mainly light-colored; cystidia 4-8μ wide; spores oblong-ellipsoid, (4-)5-7 x 2.5-3(-4)μ ....19. *P. affinis*
23. Fruit body mainly dark-colored; cystidia 7-15μ wide; spores ellipsoid, 5-8 x 2.5-3.5(-4)μ ...20. *P. velutina*
    24. Spores small, oblong-ellipsoid, 3.5-6.5(-7.5) x 2-3(-3.5)μ ....21. *P. ludoviciana*
    24. Spores mainly over 6.5μ long.. 25
25. Cystidia large, broadly cylindrical to subclavate, up to 20μ wide; spores cylindrical, 8-12(-14) x 3-4.5(-5)μ .. ..22. *P. guttulifera*
25. Cystidia small, mainly conical, up to 9μ wide; spores cylindrical to suballantoid, (6-)7-9(-10) x 2.5-3μ .....23. *P. cinerea*
    26. Hyphae simple-septate, with only an occasional clamp connection in some species 27
    26. Hyphae strictly nodose-septate 28
27. Cystidia up to 100μ in length, often slightly incrusted at the apex; hyphae not constricted at the septa; spores oblong-ellipsoid, (5-)5.5-8 x 2.5-4μ .....24. *P. cremea*
27. Cystidia under 65μ in length, unincrusted; hyphae constricted at the septa; spores broadly ellipsoid to oblong-ellipsoid, 4-6 x 2-3μ ....25. *P. burtii*

28. Spores narrow and mainly under 3μ in width 29
28. Spores 3μ or more in width ..30
29. Cystidia cylindrical-acuminate, sparingly incrusted with rectangular crystals; spores long-cylindrical to subfusiform, 10-16 x (1.2-)1.5-3μ .. ..26. *P. longispora*
29. Cystidia cylindrical-obtuse, unincrusted; spores narrowly cylindric, 6-9 x 1.5-2μ .....27. *P. subalutacea*
30. Cystidia large, up to 360μ in length; spores broad-fusiform, 9.5-15(-18) x 5-7.5(-8)μ ....28. *P. ochroleuca*
30. Cystidia smaller; spores under 10μ in length 31
31. Cystidia large, obclavate-undulate, over 75μ long; spores broad-ellipsoid to slightly subovate, 7.5-9.5(-10) x 4-5μ .....29. *P. argillacea*
31. Cystidia small, mainly cylindrical-capitate, up to 45μ long; spores broad-ellipsoid, (4-)6-7(-7.5) x 3-5μ .....30. *P. sambuci*

Description of the Species

In the following descriptions of species the reference to a figure in the citation pertains to the illustrations accompanying this text.

1. **Peniophora accedens** (Bourd. & Galz.) Wakef. & Pears., Brit. Mycol. Soc. Trans. 6:140. 1920. Figure 1.

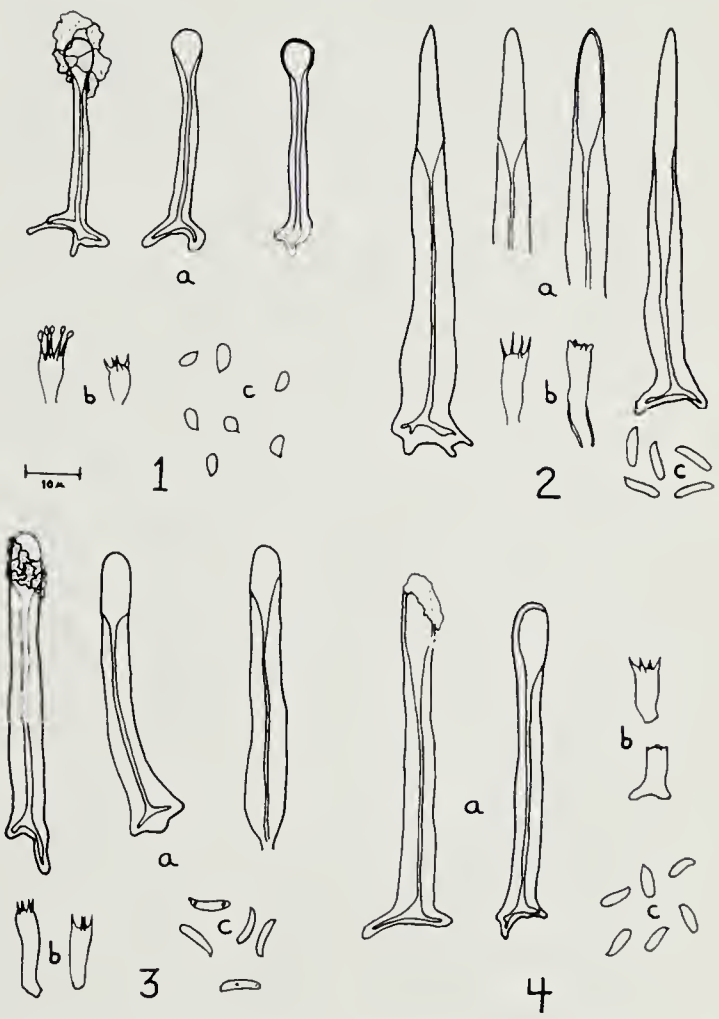
   Syn.: *Peniophora glebulosa* ssp. *accedens* Bourd. & Galz., Bull. Soc. Myc. France, 28:386. 1913.

Fruit body resupinate, effused, adnate, membranous, with a very scant subiculum; surface discontinuous, pruinose, appearing minutely setose in side-view, with the swollen apices of the cystidia appearing as small water droplets; margin indeterminate; color ranging from Grey Stone (13A2) to Manila (12C5).

Hyphae hyaline, nodose-septate, often indistinct, naked, thin-walled, 1.5-2.5(-3) μ in diameter. Cystidia numerous, cylindrical, possessing a capillary lumen that widens into a thin-walled bulbous apex, apical bulb often surrounded by a mucilaginous crystalline material and measuring 5-7(-10.5)μ in diameter, rooted at the base, walls nonamyloid and dissolving in 10 per cent KOH, stem measuring 2.5-5(-6)μ in diameter, whole measuring (35-)40-65(-90)μ in length. Basidia short-clavate, with 4(-5) sterigmata, (7.5-)8-12(-17.5) x (3.5-)4-5μ. Spores ellipsoid to broad-ellipsoid, hyaline, smooth, nonamyloid, (3-)3.5-5.5 x 2-3 (-3.5)μ.

On decayed deciduous wood. Common in Illinois. Also known from British Columbia, Denmark, France, Ontario, Quebec, Sweden, Iowa, Massachusetts, Oregon, and Rhode Island.

Illinois material examined: Funk's Grove, McLean County, XI.24.1961, S. F. & A. E. Liberta 218 (ISU); XI.6.1962, A. E. Liberta 319 (ISU); East Bay Camp, Lake Bloomington, McLean County, X.24.1963, A. E. Liberta & R. J. Harris 5 (RJH), 449, 450 (ISU); west edge of Crab Orchard Lake, Carbondale, XI.-23.1963, A. E. Liberta & R. J. Harris



Figures—1. *Peniophora accedens.* (a) Three cystidia, one with an incrusted apex; (b) Two basidia, one bearing young spores on the sterigmata; (c) Spores. 2. *Peniophora subulata.* (a) Four cystidia, two showing only the upper portion; (b) Two basidia, one with thickened basal walls; (c) Spores. 3. *Peniophora gracillima.* (a) Three cystidia, one with incrustation; (b) Two basidia; (c) Spores. 4. *Peniophora pirina.* (a) Two cystidia, one with an incrusted apex; (b) Two basidia; (c) Spores.

35 (RJH); Lowden Memorial Park, Oregon, VI.6.1964, E. J. Disselhorst & R. J. Harris 36, 37 (RJH).

P. accedens is separated from other members of *Peniophora* by means of the bulbous apex of the cystidia, rather uniformly narrow cystidial stem whose walls dissolve in 10 per cent KOH, and the short ellipsoid spores.

2. **Peniophora subulata** (Bourd. & Galz.) Donk, Mededel, Ned. Myc. Ver. 18-20:165. 1931. FIGURE 2.

Syn.: *Peniophora glebulosa* ssp. *subulata* Bourd. & Galz., Bull. Soc. Myc. Fr., 28:385. 1913.

Peniophora cretacea ssp. *subulata* (Bourd. & Galz.) Bourd & Galz., Hym. de Fr., p. 289. 1928.

Fruit body resupinate, widely effused, adnate, membranous to subwaxy; surface continuous, minutely tuberculate, hispid in profile; margin thinning, and arachnoid; color Oyster White (10B1) to between Ivory (10B2) and Straw (10F2).

Hyphae hyaline, nodose-septate, naked, thin to slightly thick-walled, 2-3μ in diameter. Cystidia numerous, narrowly conical, with capillary lumen of stem widening into a thin-walled lance-like apex (10-)15-20μ long, apices often incrusted with crystalline matter, rooted at the base, walls slightly amyloid and dissolving in 10 per cent KOH, (50-)60-80 x (5.5-)7-13(-15)μ. Basidia clavate, bearing four sterigmata, basal walls often thickened, 11-20 x (3-)4-4.5μ. Spores narrowly cylindrical, often slightly curved at the apiculus end, hyaline, smooth, nonamyloid, (6-)6.5-8(-9) x 1.5-2(-2.5)μ.

On decayed deciduous wood. Rare, and previously unreported for Illinois. Also known from British Columbia, Denmark, France, Gaspé Peninsula, Ontario, Sweden, New York, and Oregon.

Illinois material examined: White Pines State Park, Oregon, VI.6.1964, E. J. Disselhorst & R. J. Harris 561 (ISU), 57, 58, 59 (RJH).

P. subulata is closely related to *P. hirtella*, which has yet to be reported for Illinois. *P. hirtella*, however, has much narrower cystidia (4-7μ), and somewhat broader spores than does *P. subulata*.

3. **Peniophora gracillima** (Ellis & Everh. ex Rogers and Jackson) G. H. Cunn., Farlowia 1:317. 1943. FIGURE 3.

Syn.: *Peniophora glebulosa* sensu Bres., Burt, Missouri Bot. Gard. Ann. 12:282. 1926.

Fruit body resupinate, effused, adnate, membranous to subwaxy; surface often appearing somewhat merulioid, minutely granulose, and hispid in profile; margin thinning and pruinose; color ranging from Woodash (27A1) to various shades of grey, or from Sunset (10C4) to Sunlight (10H4).

Hyphae hyaline, nodose-septate, slightly thick-walled, naked, 2-3μ in diameter. Cystidia numerous, cylindrical-obtuse, possessing a capillary lumen which widens rather abruptly into a thin-walled, cylinder-like obtuse apex, apex measuring 9.5-18(-20) x (4.3-)5-8μ, stem (5.5-)7-9.5(-10)μ wide, whole measuring (55-)60-100(-170)μ in length, rooted at the base, walls amyloid and dissolving in 10 per cent KOH, often slightly incrusted with a crystalline mass. Basidia subclavate to clavate, 12-25(-30) x 4-4.5(-5)μ. Spores narrowly cylindrical to suballantoid, smooth, hyaline, nonamyloid, (6.5-)7-9.5 x 1.5-2(-2.2)μ.

On decayed deciduous wood. Rare, and previously unreported for Illinois. Also known from Australia, Austria, British Columbia, England, Italy, Manitoba, New Zealand, Ontario, Quebec, South Africa, Sweden, Colorado, Idaho, Maine, Montana, Nebraska, New Hampshire, New Jersey, New York, Oregon, Vermont, and Washington.

Illinois material examined: White Pines State Park, Oregon, VI.6.1964, E. J. Disselhorst & R. J. Harris 53 (RJH).

Several species of *Peniophora*, not yet reported for Illinois, closely resemble *P. gracillima*. The only real basis for separation of these species has been the manner in which the capillary lumen widens. In *P. gracillima* the capillary lumen widens rather abruptly; whereas in the other related species it widens gradually, or when widening abruptly the apex is stout, and more pronouncedly obtuse than in *P. gracillima*.

4. **Peniophora pirina** Bourd. & Galz., Bull. Soc. Mycol. Fr. 28:387. 1913. FIGURE 4.

Fruit body resupinate, effused, adnate, subwaxy; surface somewhat discontinuous, pruinose, hispid in profile; margin indeterminate to very thin; color Grey Stone (13A2) to Old Ivory (12C3) or Crash (12D3).

Hyphae hyaline, nodose-septate, amyloid, thick-walled, naked, 2.5-3.5(-4)μ in diameter. Cystidia subcylindrical-obtuse, possessing a capillary lumen that broadens at the apex giving a slight hooded appearance to the tip, apex often incrusted with crystalline matter and

measuring 10-25 x 5-7μ, somewhat broadened and rooted at the base, walls amyloid and collapsing in 10 per cent KOH, stem 4-6.5(-7.5)μ wide, whole measuring 50-85μ in length. Basidia subclavate to clavate, bearing four sterigmata, basal walls slightly thickened, 10-20(-25) x (4-)4.5-5μ. Spores cylindrical, slightly curved at apiculus end, hyaline, smooth, nonamyloid, 5-6.5(-7) x 2-2.5(-2.7)μ.

On decayed deciduous wood. Rare, and previously unreported for Illinois. Also known from France, Gaspé Peninsula and Ontario.

Illinois material examined: Shawnee National Forest, Carbondale, XI.23.1963, A. E. Liberta & R. J. Harris 54 (RJH).

P. pirina is so closely related to *P. calothrix* that one questions the validity of considering them as separate species. Weresub (1961) believes that the type specimens, at least, are distinct from one another. Probably the best separating feature is the degree of cystidial hooding. *P. pirina* has only slight hooding; whereas *P. calothrix* has very pronounced hooding.

5. **Peniophora calothrix** (Pat.) Rogers & Jacks., Farlowia 1:316. 1943. FIGURE 5.

   Syn.: *Corticium calothrix* Pat., Cat. Rais. Pl. Cel. Tunisie, p. 59. 1897.

   Peniophora glebulosa ssp. *pirina* Bourd. & Galz., Soc. Myc. Fr. Bul. 28:387. 1913.

   Peniophora delectans Overh., Mycol. 26:513. 1934.

Fruit body resupinate, moderately to widely effused, adnate, membranous; surface discontinuous, hispid in profile, pruinose with the incrusted caps of cystidia giving a droplet appearance; margin indeterminate; color Whitish Grey (35A1) to Cement Grey (46A1).

Hyphae hyaline, nodose-septate, amyloid, naked, thick-walled, (1.5-)2.5-4(-5)μ in diameter. Cystidia occurring frequently, cylindrical-obtuse, possessing a capillary lumen which widens into a noticeable one sided hooded apex, usually incrusted at the apex, base slightly broader and rooted, walls amyloid and dissolving in 10 per cent KOH, 50-85 (-125) x 5-7(-8.5)μ. Basidia stout, cylindrical to subclavate, basal walls often somewhat thickened, (8.5-)9.5-14(-17.5) x (3.75-)4.5-5(-5.5)μ. Spores cylindrical, smooth, nonamyloid, hyaline, sometimes slightly curved at the apiculus end, (4.5-)5-7(-7.5) x (1.5-)2-2.5(-3)μ.

On decayed deciduous wood. Rare, and previously unreported for Illinois. Also known from Denmark, France, Gaspé Peninsula, Ontario, Sweden, Tunisia, Iowa, New York, Oregon, and Tennessee.

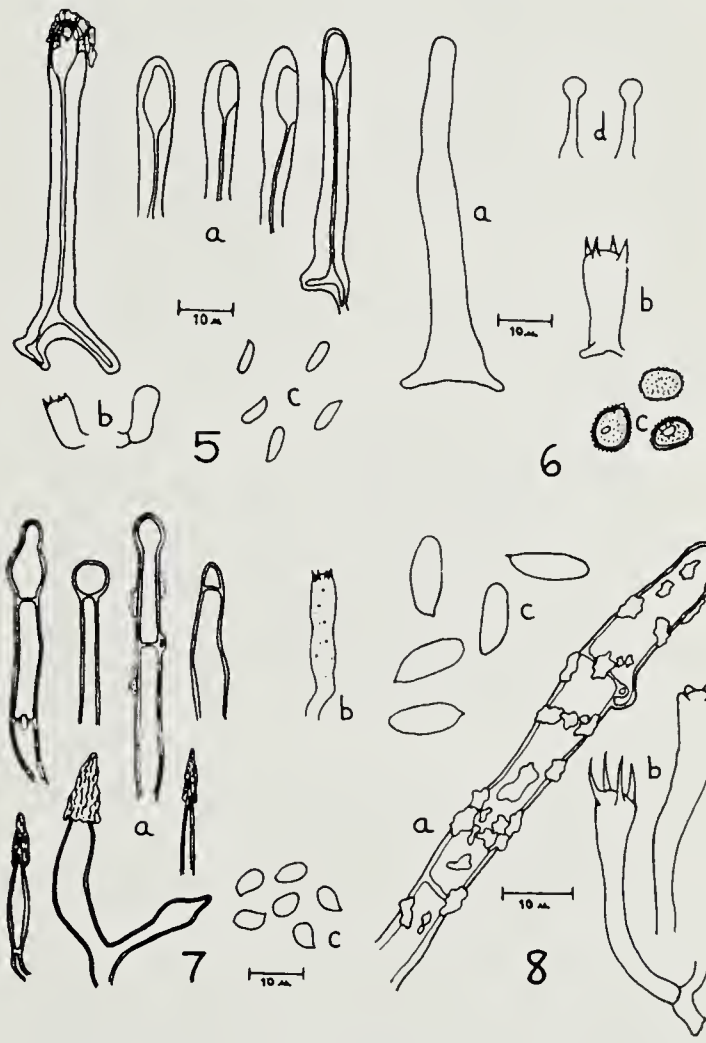
Illinois material examined: west edge of Crab Orchard Lake, near Carbondale, XI.23.1963, A. E. Liberta & R. J. Harris 560 (ISU), 55, 56 (RJH).

See the discussion under 4 *P. pirina*.

6. **Peniophora praeterita** Jacks., Canad. Jour. Res. 28(C):533. 1950. FIGURE 6.

Fruit body resupinate, effused, adnate, gelatinous; surface pruinose; margin very thin and finely pruinose; color Oyster White (10B1), or Marguerite Yellow (10C1) to Greyish (7A1).

Hyphae hyaline, nodose-septate, horizontal and close to the substrate, with thin gelatinized walls, very scant in the



FIGURES—5. *Peniophora calothrix*. (a) Five cystidia, three showing only the upper portion; (b) Two basidia; (c) Spores. 6. *Peniophora praeterita*. (a) Cystidium; (b) Basidium; (c) Spores, two with thickened walls; (d) Two cystidioles. 7. *Peniophora pallidula*. (a) Seven cystidial types, three with incrusted apices; (b) Basidium with granular contents; (c) Spores. 8. *Peniophora aspera* (a) Cystidium with sparse incrustation; (b) Two basidia; (c) Spores.

subiculum, 1.5-2.5μ in diameter. Cystidia few to frequent, subcylindrical, tapering slightly toward the obtuse apex, somewhat rooted at the base, naked, flexile, thin-walled, (48-)50-90(-92) x 6-10(-11)μ. Cystidioles rare, cylindrical-capitate, often rooted at the base, naked, thin-walled, (12-)14-20(-25) x 2.5-3(-5)μ, apical bulb 4-5μ in diameter, stem 2.5-3μ in diameter. Basidia stoutly subclavate, often rooted at the base, bearing 4-5 sterigmata, (15-)17-25 x 5-9μ. Spores mostly subglobose, but occasionally broadly ellipsoid, echinulate, ornamentation persisting in KOH, hyaline, nonamyloid, somewhat thick-walled, apiculate, 6-9 x 4.5-7.5μ.

On decayed deciduous wood. Common in Illinois. Also known from New Zealand, Ontario, and Connecticut.

Illinois material examined: Funk's Grove, McLean County, VII.10.1962, A. E. Liberta 320, 323, 324 (ISU); X.28.1963, R. J. Harris 30 (RJH); next to Mississippi River, Quincy, XI.9.1963, R. J. Harris 38 (RJH), 555 (ISU); Shawnee National Forest, Carbondale, XI.23.1963, A. E. Liberta & R. J. Harris 39 (RJH).

P. praeterita can be distinguished from other species by means of its nonamyloid echinulate spores, and persistent ornamentation in KOH.

7. **Peniophora pallidula** (Bres.) Bres. apud Bourd. & Galz., Soc. Myc. Fr. Bul. 28:390. 1913. FIGURE 7.

   Syn.: *Gloeocystidium pallidulum* (Bres.) Höhn. & Litsch., Österr. Bot. Zeitschr. 58:471. 1908.

   Peniophora alutaria Burt, Missouri Bot. Gard. Ann. 12:332. 1926.

   Peniophora laminata Burt, Missouri Bot. Gard. Ann. 12:246. 1926.

   (For further synonymy see Rogers and Jackson, 1943, p. 313.)

Fruit body resupinate, widely effused, adnate, submembranous; surface discontinuous, verruculose-pruinose; margin very thin and pruinose; color cream or Sand (13B2) to Miami Sand (13B3).

Hyphae hyaline, nodose-septate, scant in the subiculum, thin-walled, naked to slightly incrusted, 2-4μ in diameter. Cystidia many, of various shapes, ranging from acicular to subulate, to cylindrical-capitate; acicular to subulate type bearing a conical cap of crystals at the apex, somewhat thick-walled, sometimes branching and giving rise to another cystidia of either type, 17-40 x (2.5-)3-7μ; cylindrical-capitate type often septate, with or without a clamp connection at the septum, shape of the apex varying considerably, naked to slightly incrusted, slightly thick-walled, (20-)30-70(-100) x (3.5-)4-7μ. Gloeocystidia absent. Basidia subclavate, bearing 4 sterigmata, contents granulose, (10-)15-25 x (3-)3.5-4.5(-5)μ. Spores mainly oval, flattened on one side, slightly depressed near apiculus end, smooth, hyaline, nonamyloid, 3.5-6 x 2.5-3.5(-4)μ.

On decayed deciduous wood. Somewhat common but previously unreported for Illinois. Also known from Denmark, France, Ontario, Sweden, Michigan, New York, Pennsylvania, Tennessee, and Vermont.

Illinois material examined: Fox River, Charleston, V.23.1959, A. E. Liberta 15 (AEL); Funk's Grove, McLean County, V.4.1962, A. E. Liberta 273 (AEL); X.14.1961, A. E. Liberta 235 (ISU).

The various shapes of the cystidia, and the oval spores are the distinguishing features of this species.

8. **Peniophora aspera** (Pers.) Sacc., Fl. Ital. Crypt. Hymen., p. 1182. 1916. FIGURE 8.

   Syn.: *Corticium setigerum* (Fries) Karst., Bidr. Känned. Finl. Nat. Folk. 37:143. 1882.

   Odontia setigera (Fries) Miller, Mycol. 26:19. 1934.

   Peniophora setigera (Fries) Höhn. and Litsch., Ann. Mycol. 4:289. 1906.

   Thelephora aspera Pers., Mycol. Eur. 1:153. pl. (5), fig. (4). 1822.

   (For further synonymy see Rogers and Jackson, 1943, p. 283.)

Fruit body resupinate, widely effused, adnate to somewhat separable depending on substrate, membranous; surface continuous, appearing minutely odontoid because of the projecting cystidia arising from wart-like bases of tissue, cracking in dry specimens, and revealing the white mycelial strands of the subiculum; margin thinning out, pruinose or sometimes arachnoid; color greyish white to Cream (9D2).

Hyphae hyaline, nodose-septate, somewhat thick-walled, naked or sometimes incrusted, loosely arranged in the subiculum to compact in the hymenium, 3-5(-6)μ in diameter. Cystidia few, cylindrical, septate, often having a clamp connection at the septum, sparsely incrusted with large coarse crystals, thick-walled, (60-)70-240 x 6-9(-12)μ. Gloeocystidia absent. Basidia subclavate, 22-

38(-40) x 5.5-7(-8)μ, bearing 4 sterigmata which become stout at the base, up to 6μ long. Spores oblong-elliptical, somewhat flattened on one side, some slightly curved, nonamyloid, smooth, apiculate, 7.5-11.5(-12) x 3-4.5μ.

On decayed deciduons wood. Common throughout Illinois. Also known from Australia, Denmark, Ukraine, New York, and Virginia.

Illinois material examined: Fox Ridge State Park, Charleston, X.5.1963, R. J. Harris 11 (RJH); East Bay Tree Farm, Lake Bloomington, McLean County, X.24.1963, A. E. Liberta & R. J. Harris 17 (RJH); next to Mississippi River, Quincy, XI.9.1963, R. J. Harris 19, 20 (RJH).

P. aspera can be readily distinguished from other species of *Peniophora* by means of its large septate cystidia, which are sparingly incrusted with large coarse crystals, and by its odontoid surface. *P. subtestacea* is similar to *P. aspera*, but differs in the color and appearance of the hymenial surface. (See Slysh, 1960, p. 48.)

9. **Peniophora byssoides** (Pers. ex. Fries) Bres. apud Brinkm., Westf. Prov. Ver. Jahresben. 26:130. 1898. FIGURE 9.

Syn.: *Thelephora byssoides* Pers. ex. Fries, Syst. Mycol. 1:452. 1821.

Corticium byssoideum (Pers. ex Fries) Fries, Hymen. Eur., p. 659. 1874.

Coniophora byssoideus (Pers. ex Fries) Karst., Bidr. Känned. Finl. Nat. Folk. 37:160. 1882.

Peniophora sordescens (Karst.) Sacc., Syll. Fung. 9:240. 1891.

Peniophora muscorum (Schroet.) Höhn., Ann. Mycol. 3:325. 1905. (For further synonymy see Rogers and Jackson, p. 275, 1943.)

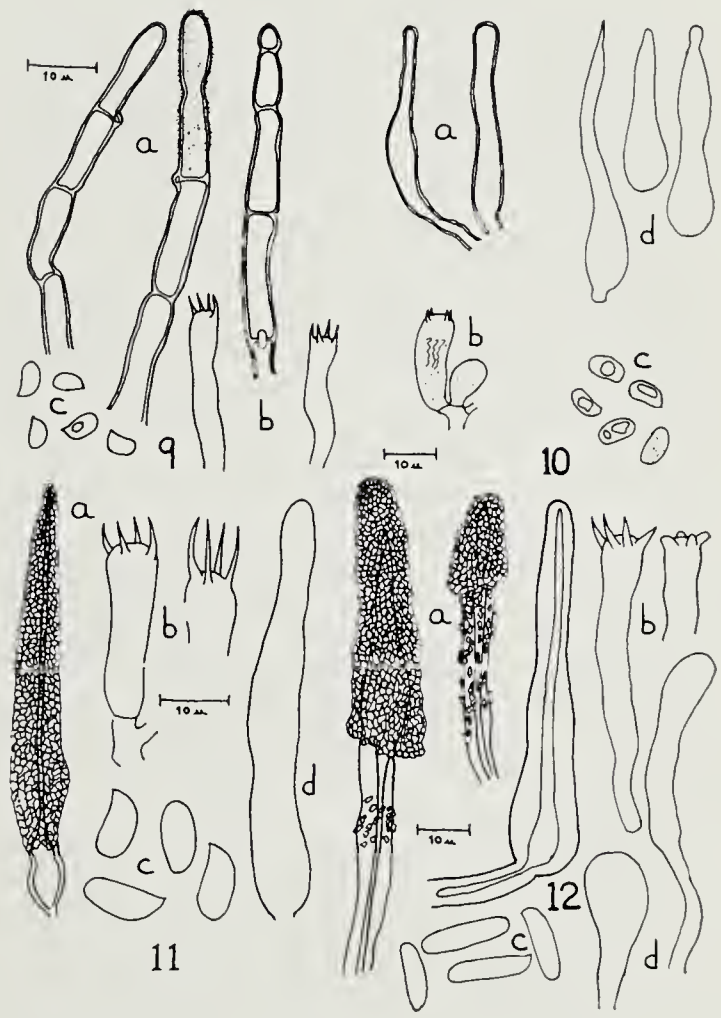
Fruit body resupinate, widely effused, adnate, submembranous; surface discontinuous, velutinate; margin thinning out and minutely granulose, greyish; color Cream (9D2) to Pinard Yellow (9J2).

Hyphae hyaline to faintly tinted, nodose-septate, rather loosely arranged, naked, thin-walled, 3-5μ in diameter. Cystidia occurring often, cylindrical, obtuse at the tip, narrowing towards the base, incrusted with minute hair-like crystals or not incrusted, tinted, septate, often constricted at the septa which may or may not bear clamp connections, thin to slightly thick-walled, 35-85(-140) x 3.5-5.5μ. Gloeocystidia absent. Basidia subclavate, 17-25 X 3-4.5(-6)μ, bearing 4 sterigmata. Spores broad-ellipsoid, smooth, hyaline or slightly tinted, nonamyloid, apiculate, 4-5(-6) x 2-3μ.

On decayed deciduous wood. Rare, and previously unreported for Illinois. Also known from Australia, Canada, Denmark, France, Great Britain, New Zealand, Sweden, West Indies, Iowa, Massachusetts, New York, Oregon, and Vermont.

Illinois material examined: East Bay Tree Farm, Lake Bloomington, McLean County, X.24.1963, A. E. Liberta & R. J. Harris 460 (ISU).

P. byssoides is easily recognized by its narrow, slightly tinted, septate cystidia. Other distinguishing cystidial characteristics are the constrictions oc-



FIGURES 9. *Peniophora byssoides*. (a) Three cystidia, one finely incrusted; (b) Two basidia; (c) Spores, one with an oil droplet. 10. *Peniophora tenuis*. (a) Two cystidia; (b) Basidium with both granular and resinous contents; (c) Spores, four with oil droplets and one granular; (d) Three gloeocystidia. 11. *Peniophora pubera*. (a) Incrusted cystidium; (b) Two basidia; (c) Spores; (d) Gloeocystidium. 12. *Peniophora mutata*. (a) Three cystidia, two incrusted and one naked; (b) Two basidia; (c) Spores; (d) Two gloeocystidia.

curring at many of the septa, and the often present hair-like incrusting crystals.

10. **Peniophora tenuis** (Pat.) Massee, Linn. Soc. Bot. Jour. 25:149. 1889. FIGURE 10.

Syn.: *Corticium tenue* Pat., Rev. Mycol. 7:152. 1885.

Peniophora praetermissa Karst., Bidr. Känned. Finl. Nat. Folk. 48:423. 1889.

Gloeocystidium tenue (Pat.) Höhn. & Litsch., Wiesner-Festschr. p. 70. 1908.

Peniophora pertenuis (Karst.) Burt, Missouri Bot. Gard. Ann. 12:315. 1926.

(For further synonymy see Rogers and Jackson, 1943, p. 322.)

Fruit body resupinate, widely effused, adnate, subwaxy; surface discontinuous, pruinose to mealy, somewhat hispid in profile; margin thinning, and minutely fibrillose; color greyish white (approaching 11A1).

Hyphae hyaline, nodose-septate, thin-walled, incrusted or naked, 2.5-4.5μ in diameter. Cystidia few to frequent, shape varying but mainly cylindrical with a slight bulge near the base, naked or rarely with some incrustation, thin to slightly thick-walled, (30-)40-60(-80) x 5-7(-8)μ. Gloeocystidia few to frequent, obclavate to subulate, flexuous, slender tips often collapsing, contents usually homogeneous, 30-75(-80) x (6-)7-12(-16)μ. Basidia broadly subclavate, contents granulose, 20-25(-30) x (6-)7-10μ. Spores oblong-ellipsoid, smooth, hyaline, nonamyloid, granulose or containing one or more large oil droplets, 7.5-10(-12) x (3.5-)4-6μ.

On decayed deciduous wood. Common, but previously unreported for Illinois. Also known from Austria, Bermuda, Canada, Denmark, Finland, France, Germany, Jamaica, Poland, South Africa, Sweden, District of Columbia, Idaho, Massachusetts, Montana, New Hampshire, New Jersey, Oregon, and Washington.

Illinois material examined: Funk's Grove, McLean County, V.17.1962, A. E. Liberta 265 (ISU); X.13.1962, A. E. Liberta 259, 263 (ISU); IV.28.1964, R. J. Harris 48 (RJH); Mississippi River area, Quincy, XI.9.1963, R. J. Harris 21, 49 (RJH).

P. tenuis is characterized by its rather large obclavate to subulate, flexuous gloeocystidia, and variously shaped cystidia.

11. **Peniophora pubera** (Fries) Sacc., Syll. Fung. 6:646. 1888. FIGURE 11.

Syn.: *Corticium puberum* (Fries) Fries, Epicr. Syst. Mycol., p. 562. 1838.

Hyphoderma puberum (Fries) Wallr., Fl. Krypt. Germ. 2:576. 1833.

Hypochnus puberus (Fries) Bon., Handb., p. 159. 1851.

Peniophora tenuissima Peck, New York State Mus. Bul. 157: 114. 1912.

(For further synonymy see Rogers & Jackson, 1943, p. 325.)

Fruit body resupinate, widely effused, adnate, sub-waxy; surface continuous, deeply cracking when dry, setulose; margin thinning out; color varying, from whitish to Cream (9D2-9F2), to Cinnamon (12E7).

Hyphae hyaline, nodose-septate, compact, thin-walled in the subhymenium to thick-walled basally, 3-5μ in diameter. Cystidia occurring frequently, conic to somewhat fusiform, heavily incrusted, (50-)55-125 x 8.5-16(-18)μ. Gloeocystidia rare, cylindrical and flexuous, (45-)50-80 x (5-)7.5-10μ. Basidia broad-cylindrical to subclavate, 20-30 x 5.5-9μ, bearing 4 sterigmata up to 6μ long. Spores oblong-elliptical, somewhat flattened on one side, very slightly curved, smooth, hyaline, nonamyloid, apiculate, 7.5-9.5 x 3.5-4.5μ.

On decayed deciduous wood. Very common throughout Illinois, but previously unreported. Also known from Australia, Austria, Canada, Denmark, France, Germany, Great Britain, Italy, Sweden, Alabama, District of Columbia, Florida, Idaho, Kentucky, Louisiana, Maryland, Massachusetts, Missouri, Montana, New Hampshire, New Jersey, New York, Oregon, Rhode Island, Virginia, Washington, and Wisconsin.

Illinois material examined: Funk's Grove, McLean County, IV.23.1962, A. E. Liberta 294 (ISU); V.12.1962, A. E. Liberta 302 (ISU); VI.23.1962, A. E. Liberta 246, 268 (ISU); west edge of Crab Orchard Lake, XI.23.1963, A. E. Liberta & R. J. Harris 2, 3 (RJH); White Pines State Park, Oregon, Illinois, VI.6.1964, E. J. Disselhorst & R. J. Harris 9 (RJH); next to Mississippi River, Quincy, Illinois, XI.9.1963, R. J. Harris 32 (RJH).

P. pubera is very similar microscopically to other members of the genus, but can be distinguished from them by its well developed setulose fructification, large cystidia, nodose-sep-

tate hyphae, and the presence of gloeocystidia. The rare gloeocystidia may easily be overlooked, and therefore a careful examination of the crushed mount is necessary.

12. **Peniophora mutata** (Peck) Höhn. & Litsch., K. Akad. Wiss. Wien Math.-Nat. Kl. Sitzungsb. 115, I:-1580. 1906. FIGURE 12.

Syn.: *Peniophora Allescheri* (Bres.) Sacc. & Syd., Syll. Fung. 16:194. 1902.

Corticium mutatum Peck, New York State Mus. Rept. 43:69. 1890.

Peniophora cremea ssp. *Allescheri* (Bres.) Bourd. & Galz., Hymen. de France, p. 304. 1928.

(For further synonymy see Rogers and Jackson, 1943, p. 313).

Fruit body resupinate, widely effused, adnate, membranous and becoming subwaxy with age; surface continuous, finely pruinose, often sparingly tubercular, cracking and exposing the white mycelial strands of the subiculum, becoming slightly reflexed at the fissures; margin radiately fibrillose, often with brownish rhizomorphs, at times somewhat reflexed; color ranging from Vanilla (10C3) to Leghorn (10D3), from Corn Husk (10E6) to Mellow-glow (10I6), and from Spice-gold (13B12) to Pheasant (13L12).

Hyphae hyaline, nodose-septate, thin-walled, incrusted or not incrusted, 3-4.5μ in diameter. Cystidia rare to few, subcylindrical-obtuse to subconical, incrusted, walls thickened, mainly immersed, (30-)50-100(-120) x 8-12(-15)μ. Gloeocystidia frequent, varying in shape, but mostly cylindrical to clavate, (25-)40-80 x (7-)8.5-14μ. Basidia clavate, with 4 broad sterigmata, (30-)40-60(-70)μ. Spores cylindrical, somewhat flattened on one side, smooth, nonamyloid, hyaline, (9-)10-16.5 x (3-)3.5-4.5μ.

On decayed deciduous wood. Rare in Illinois. Also known from Austria, Canada, Denmark, France, Germany, Japan, Latvia, Sweden, West Indies, Alabama, Florida, Idaho, Indiana, Maine, Michigan, Minnesota, Missouri, New Hampshire, New Jersey, New York, Ohio, South Dakota, Vermont, Washington, and Wisconsin.

Illinois material examined: River Forest, X.1902, E. T. and S. A. Harper 631 (FH).

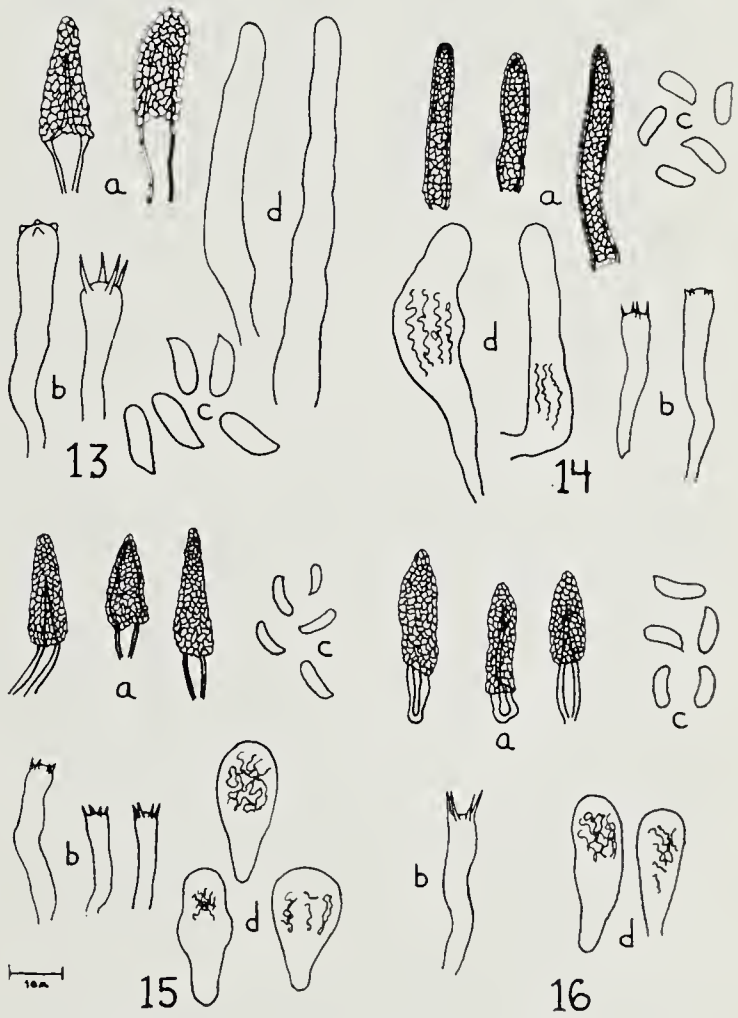
P. mutata is characterized by its large incrusted cystidia, cylindrical to subclavate gloeocystidia, large clavate basidia, and large cylindrical spores.

The gloeocystidia in this species are questionable. The possibility exists that the gloeocystidia are actually developing basidia. Further study is necessary so that the proper term can be attributed to these structures.

13. **Peniophora heterocystidia** Burt, Mo. Bot. Gard. Ann. 12:293. 1926. FIGURE 13.

Syn.: *Peniophora Kauffmanii* Burt, Mo. Bot. Gard. Ann. 12:296. 1926.

Fruit body resupinate, widely effused, adnate, membranous; surface cracking and exposing the whitish subiculum, becoming slightly reflexed at the fissures, pilose-granulose; margin thinning out, fibrillose, often appearing waxy-white; color Pearl Blush (12A5) or Cork (12B7).



FIGURES 13. *Peniophora heterocystidia.* (a) Two incrusted cystidia; (b) Two basidia; (c) Spores; (d) Two gloeocystidia. 14. *Peniophora incarnata.* (a) Three incrusted cystidia; (b) Two basidia; (c) Spores; (d) Two gloeocystidia with resinous contents. 15. *Peniophora nuda.* (a) Three incrusted cystidia; (b) Three basidia; (c) Spores. (d) Three gloeocystidia with resinous contents. 16. *Peniophora violaceo-livida.* (a) Three incrusted cystidia; (b) Basidium; (c) Spores; (d) Two gloeocystidia with resinous contents.

Hyphae hyaline, nodose-septate, naked to moderately incrusted, thin-walled, semi-compact in the subiculum, becoming compact in the hymenium, 3-5.5μ in diameter. Cystidia occurring frequently, heavily incrusted, conical at the incrusted portion and tapering at the unincrusted base, thick-walled, (25-)35-50 x (6-)8.5-10(-12)μ. Gloeocystidia abundant, cylindrical and tapering at the base, thin-walled, many projecting up to 60μ, (40-)55-125 x 6-8.5(-10)μ. Basidia subclavate, (20-)30-35(-45) x 6-8μ, bearing 4 sterigmata up to 6μ in length. Spores cylindrical, flattened on one side, slightly curved at the apiculus end, hyaline, smooth, nonamyloid, 9.5-14(-15) x 3.5-4.5μ.

On decayed deciduous wood. Common in Illinois. Also known from Canada, Mexico, Connecticut, District of Columbia, Indiana, Kentucky, Mississippi, Missouri, New Jersey, New York, Ohio, Pennsylvania, and Vermont.

Illinois material examined: Glencoe, E. T. & S. A. Harper 662, 646 (FH); Fox Ridge State Park, Charleston, X.5.1963, R. J. Harris 15 (RJH), 489 (ISU).

It is questionable whether or not the gloeocystidia of *P. heterocystidia* are true gloeocystidia or merely a second type of cystidium. Many of these gloeocystidia project up to 60μ, are non-resinous, and arise at the level of the hymenium, and therefore could justifiably be called cystidia. However, until further study is undertaken it is best to retain the term gloeocystidium for this structure.

P. heterocystidia can be distinguished from other species of *Peniophora* by its long, narrow, cylindrical gloeocystidia, rather short and broad incrusted cystidia, and large cylindrical spores.

14. **Peniophora incarnata** (Pers. ex Fries) Karst., Hedwigia 28:27. 1889. FIGURE 14.

    Syn.: *Thelephora incarnata* Pers. ex Fries, Syst. Myc. 1:444. 1821.

Fruit body resupinate, effused, adnate, waxy; surface continuous, pruinose, cracking and revealing the white subiculum; margin thinning and becoming arachnoid; color approaching Maple (11E4) or Cinnamon Pink (5C10) to various shades of orange.

Hyphae hyaline, nodose-septate, compact, naked to sometimes slightly incrusted, thin to slightly thick-walled, 3-4(-4.5)μ in diameter. Cystidia few to frequent, cylindrical to narrowly conic, incrusted, mostly immersed, 23-50(-60) x (4-)7-12μ. Gloeocystidia occurring frequently, varying in shape from cylindrical to various inflated bladder-like forms, contents resinous, 25-60(-100) x 7-15μ. Basidia narrowly long-clavate, 25-40 x 5-7μ. Spores broadly cylindrical to oblong-ellipsoid, smooth, hyaline, nonamyloid, somewhat flattened on one side, curved at apiculus end, 7-10(-12) x 2.5-4(-5)μ.

On decayed deciduous wood. Rare, and previously unreported for Illinois. Also known from Australia, Austria, Denmark, England, Finland, France, Germany, Italy, Japan, Newfoundland, New Zealand, Ontario, South Africa, Sweden, Alabama, Alaska, Colorado, District of Columbia, Florida, Iowa, Kansas, Kentucky, Maine, Maryland, Massachusetts, Missouri, New Hampshire, New Mexico, New York, Ohio, Pennsylvania, South Carolina, Vermont, West Virginia, and Wisconsin.

Illinois material examined: Embarrass River, near Charleston, IV.20.1960, D. D. McLain 200 (AEL).

The only Illinois specimen available for study appeared to be in an early growth stage. The cystidia and gloeocystidia were smaller than those measured by other mycologists.

P. incarnata may be separated from other species of *Peniophora* by means of its abundant, large cylindrical to bladder-like gloeocystidia, cylindrical to narrowly conic incrusted cystidia and often orange colored fruit body.

15. **Peniophora nuda** (Fries) Bres., I. R. Accad. Agiata Atti. III, 3:114. 1897. FIGURE 15.

    Syn.: *Thelephora nuda* Fries, Syst. Myc. 1:447. 1821.

Fruit body resupinate, occurring in small patches, eventually coalescing and becoming effused, adnate, waxy; surface continuous, pruinose, cracking in older specimens; margin very thin, nearly indistinct, somewhat lighter in color, and faintly fibrillose; color ranging from Moonmist (12A2) to Grey Stone (13A2).

Hyphae brownish, compact, difficult to separate, nodose-septate, thin to slightly thick-walled, 3-5μ in diameter. Cystidia numerous, conical, thick-walled, heavily incrusted, immersed or projecting slightly, 15-35 x 5-7(-9)μ. Gloeocystidia occurring frequently, mostly broad-obpyriform, 20-40(-45) x (10-)11-20μ. Basidia subclavate, having 4 sterigmata, often projecting above the level of the hymenium, (20-)22-30 x 5-6μ. Spores suballantoid, smooth, hyaline, nonamyloid, 7-9 x 2-3μ.

On decayed deciduous wood. Rare, and previously unreported for Illinois. Also known from Finland, France, Germany, Japan, Ontario, Sweden, Alabama, Florida, Georgia, Louisiana, Maryland, New Jersey, New York, South Carolina, Texas, Vermont, and Virginia.

Illinois material examined: Funk's Grove, McLean County, X.28.1963, R. J. Harris 18 (RJH); River Forest, E. T. & S. A. Harper 676 (labeled *P. cinerea* in FH).

E. T. and S. A. Harper's collection #676 of *P. cinerea* from River Forest, Illinois is actually *P. nuda*. This can be verified by making a crushed mount of the material in sulfuric benzaldehyde, in which the gloeocystidia are readily apparent.

P. nuda closely resembles *P. cinerea* and *P. violaceo-livida*. It can be distinguished from these two by means of its frequent broad-obpyriform gloeocystidia.

16. **Peniophora violaceo-livida** (Sommerf.) Massee, Linn. Soc. Jour. Bot. 25:152. 1889. FIGURE 16.

Syn.: *Thelephora violaceo-livida* Sommerf., Suppl. Fl. Lapp., p. 283. 1826.

Corticium violaceo-lividum (Sommerf.) Fries, Epicr. 564. 1838.

Fruit body resupinate, widely effused, adnate, waxy; surface continuous, slightly tubercular, pruinose, occasionally cracking; margin ending abruptly or very thin and pruinose; color Moonmist (12A2).

Hyphae with a brownish tint, nodose-septate, dense, slightly thick-walled, 3-4μ in diameter. Cystidia few to many, stoutly conical, heavily incrusted, thick-walled, immersed or projecting slightly, 15-30(-38) x (5)6-8(-10)μ. Gloeocystidia rare and easily overlooked, clavate, contents resinous, (15-)20-30 x (7-)8-10μ. Basidia cylindrical to subclavate, bearing 4 sterigmata, (20-)25-35 x 5-6μ. Spores cylindrical to suballantoid, smooth, hyaline, nonamyloid, 7-9(-10) x 2.5-3.5μ.

On decayed deciduous wood. Rare, and previously unreported for Illinois. Also known from Austria, Denmark, France, Italy, Lappland, Ontario, Sweden, District of Columbia, Louisiana, Maryland, Massachusetts, New Jersey, New York, and Vermont.

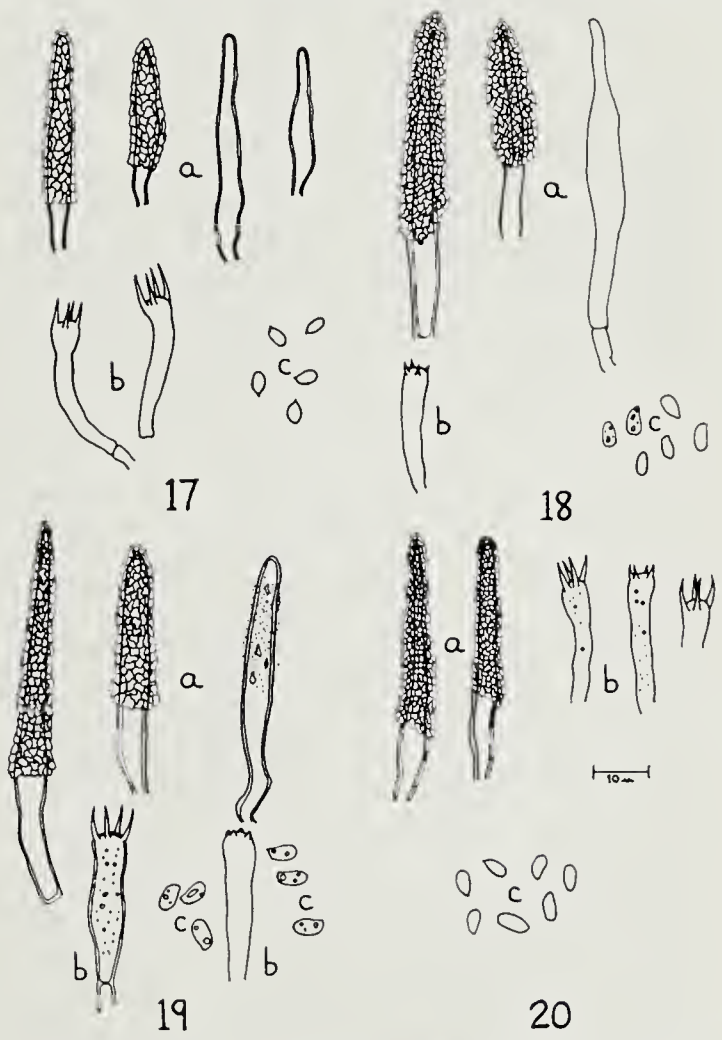
Illinois material examined: East Bay Tree Farm, Lake Bloomington, McLean County, X.24.1963, A. E. Liberta & R. J. Harris 61 (RJH).

P. violaceo-livida closely resembles *P. nuda* and *P. cinerea*. However *P. cinerea* lacks gloeocystidia, and *P. nuda* possesses more numerous broadly obpyriform gloeocystidia. A careful examination of *P. violaceo-livida* is required in order to distinguish the rare gloeocystidia.

17. **Peniophora filamentosa** (Berk. & Curt.) Burt in Coker, Elisha Mitchell Scientif. Soc. Jour. 36: 162. pl. 32, f. 5,6. 1921. FIGURE 17.

Syn.: *Corticium filamentosum* Berkeley & Curtis, Grevillea 1:178. 1873.

Peniophora unicolor Peck, N. Y. State Mus. Rept. 43:66. 1890.



FIGURES 17. *Peniophora filamentosa*. (a) Four cystidia, two incrusted and two naked; (b) Two basidia; (c) Spores. 18. *Peniophora coccineo-fulva*. (a) Three cystidia, two incrusted and one naked; (b) Basidium; (c) Spores, two with droppy contents. 19. *Peniophora affinis*. (a) Three cystidia, one partially incrusted; (b) Two basidia, one with droppy contents; (c) Spores with droppy contents. 20. *Peniophora velutina*. (a) Two incrusted cystidia; (b) Three basidia, two with droppy and granular contents; (c) Spores.

Corticium radicatum P. Hennings, Pilze Ostafrikas, 54. 1895.

Fruit body resupinate, widely effused, separable, pelliculose; surface continuous, pruinose, cracking, often flaking off and revealing the brownish layer of subhymenial hyphae, becoming vinaceous or wine-red with the application of KOH; margin consisting of compact, usually white, mycelial strands; color ranging from Sponge (14C5) to Airdale (14F6), to Citrine (14L6).

Hyphae tinted, mostly nodose-septate with occasional simple septa, incrusted in the subhymenium with golden brown mucilaginous crystals that dissolve in KOH, rather loosely arranged, whitish in the subiculum, rather thin-walled, (2.5-)3-5(-6)μ in diameter. Cystidia frequent, narrowly conic to subfusiform, incrusted with golden brown crystals that often dissolve in 3 per cent KOH leaving the cystidia naked, mostly immersed, when incrusted (28-)30-55 x (5-)6-10(-12)μ, when not incrusted the width ranges from 3.5-5μ. Basidia clavate, usually constricted near the apex, projecting above the hymenial level, bearing 4 sterigmata up to 7μ long, (15-)20-25(-29) x 4-5(-6)μ. Spores ovoid to ellipsoid, smooth, hyaline, nonamyloid, apiculate, 4-5.5 x (2-)2.5-3μ.

On decayed deciduous wood. Common in Illinois. Also known from Australia, Canada, Cuba, Denmark, France, Germany, Great Britain, Jamaica, Japan, Mexico, New Zealand, South Africa, Alabama, Arizona, Arkansas, Kentucky, Maryland, Michigan, Missouri, New Hampshire, New Jersey, New York, North Carolina, Ohio, and Vermont.

Illinois material examined: Riverside, E. T. & S. A. Harper 852 (FH); East Bay Tree Farm, Lake Bloomington, McLean County, X.24.1963, A. E. Liberta & R. J. Harris 29 (RJH).

The color reaction to KOH is the chief distinguishing characteristic of *P. filamentosa*. The pelliculose texture, the brown incrusted, narrowly conic to subfusiform cystidia, and ovoid to ellipsoid spores are also noteworthy characteristics of this species.

18. **Peniophora coccineo-fulva** (Schw.) Burt, Mo. Bot. Gard. Ann. 12:253. 1926. FIGURE 18.

    Syn.: *Phlebia coccineo-fulva* Schw., Amer. Phil. Soc. Trans., II, 4: 165. 1832.

    Peniophora rhodochroa Bres., Mycol. 17:70. 1925.

Fruit body resupinate, widely effused, somewhat separable, membranous to subwaxy; surface continuous, hirsute, often with scattered arachnoid areas; margin whitish, fibrillose, with frequent white rhizomorphs; color Burnous (9C4) or Flesh (11A2) to Blush (12A7), becoming somewhat Rust (6A12) colored with age.

Hyphae hyaline, simple-septate, heavily incrusted, somewhat thick-walled, (4-)4.5-10μ. Cystidia numerous, subconical to subfusiform, heavily incrusted, (50-)55-75(-100) x 9.5-13(-14)μ. Gloeocystidia absent. Basidia subclavate, bearing 4 sterigmata, 15-20 x 5-6(-8)μ. Spores broadly ellipsoid, 4.5-6.5(-7) x (2.5-)3-4μ.

On decayed deciduous wood. Rare, and previously unreported for Illinois. Also known from British Columbia, Finland, France, Germany, Mexico, New Brunswick, Ontario, Sweden, Alabama, Arizona, California, Colorado, Idaho, Maine, Maryland, Michigan, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Vermont, Virginia, and Wisconsin.

Illinois material examined: White Pines State Park, Oregon, VI.6.1964, E. J. Disselhorst & R. J. Harris 563 (ISU), 65 (RJH).

P. coccineo-fulva appears to be very closely related to *P. affinis* and *P. velutina*. It can be distinguished from the former by means of its wider cystidia and darker colored hymenium, and from the latter by means of its heavily incrusted hyphae.

19. **Peniophora affinis** Burt, Mo. Bot. Gard. Ann. 12:266. 1926. FIGURE 19.

    Syn.: *Peniophora laevis* sensu Burt apud Peck, New York State Mus. Bul. 54:954. 1902.

    Kneiffia laevis sensu Bres., Ann. Mycol. 1:100. 1903.

    Peniophora laevis var. affinis (Burt) Litsch., Osterr. Bot. Zeitschr. 88:117. 1939.

    (For further synonymy see Rogers and Jackson, 1943, p. 318.)

Fruit body resupinate, widely effused, somewhat separable, membranous; surface continuous, hirsute-pruinose, cracking and becoming somewhat waxy-fleshy with age; margin radiately fibrillose with many white to cream colored rhizomorphs, sometimes slightly reflexed and ending abruptly; color Cream (9D2) with a Capucine Buff (9E5) tint, less often Apricot (10F7), or between Golden Wheat (11D7) and Inca Gold (11J7).

Hyphae hyaline, simple-septate with occasional clamp connections, loosely arranged and easily distinguished in the

subiculum, becoming compact toward the hymenium, somewhat thick-walled, naked 3-6(-9)μ in diameter. Cystidia occurring frequently, somewhat narrowly conical when fully incrusted to subfusiform when naked or partly incrusted, thin to slightly thick-walled, projecting or immersed, (30-)40-85(-100) x (4-) 5.5-7.5(-8)μ. Gloeocystidia absent. Basidia subclavate to clavate, bearing 4 sterigmata, walls often somewhat thickened, contents often granular, (15-) 25-35(-42) x 4-6μ. Spores oblong-ellipsoid, somewhat flattened on one side, smooth, hyaline, nonamyloid, contents mostly with one or more large oil droplets, (4-)5-7 x 2.5-3(-4)μ.

On decayed deciduous wood. Common in Illinois. Also known from Australia, Austria, Denmark, France, Great Britain, Jamaica, Ontario, Quebec, Sweden, Ukraine, West Indies, Maine, Massachusetts, New Hampshire, New York, Oregon, Tennessee, Vermont, and Wisconsin.

Illinois material examined: Glencoe, E. T. & S. A. Harper 650, 820 (FH); Lowden Memorial Park, Oregon, VI.6.-1964, E. J. Disselhorst & R. J. Harris 62, 63 (RJH), 562 (ISU).

P. affinis so closely resembles *P. velutina* that it becomes difficult to separate the two on microscopic differences alone. The lighter colored fruit body of *P. affinis* seems to be the only characteristic used to separate these species. Culture studies must be made to help determine the relationship between these two species.

20. **Peniophora velutina** (DC ex Fries) Cooke, Grevillea 8:21. 1879. FIGURE 20.

Syn.: *Thelephora velutina* DC., Fl. Franc. 6:33. 1815.

Fruit body resupinate, widely effused, somewhat separable, membranous; surface continuous, pruinose, somewhat hispid in profile, cracking with age; margin whitish, radiately fibrillose with frequent white rhizomorphs, sometimes slightly reflexed; color Tansan (12B6) to Aloma (13C7).

Hyphae hyaline, simple-septate, naked, thin to slightly thick-walled, (4-)5-8(-10)μ in diameter. Cystidia occurring frequently, subconical, heavily incrusted, slightly thick-walled, 50-85(-120) x 7-11 (-15)μ. Gloeocystidia absent. Basidia subclavate to clavate, bearing 4 sterigmata, 20-35(-40) x 5-7μ. Spores ellipsoid, somewhat flattened on one side, hyaline, nonamyloid, smooth, 5-8 x 2.5-3.5(-4)μ.

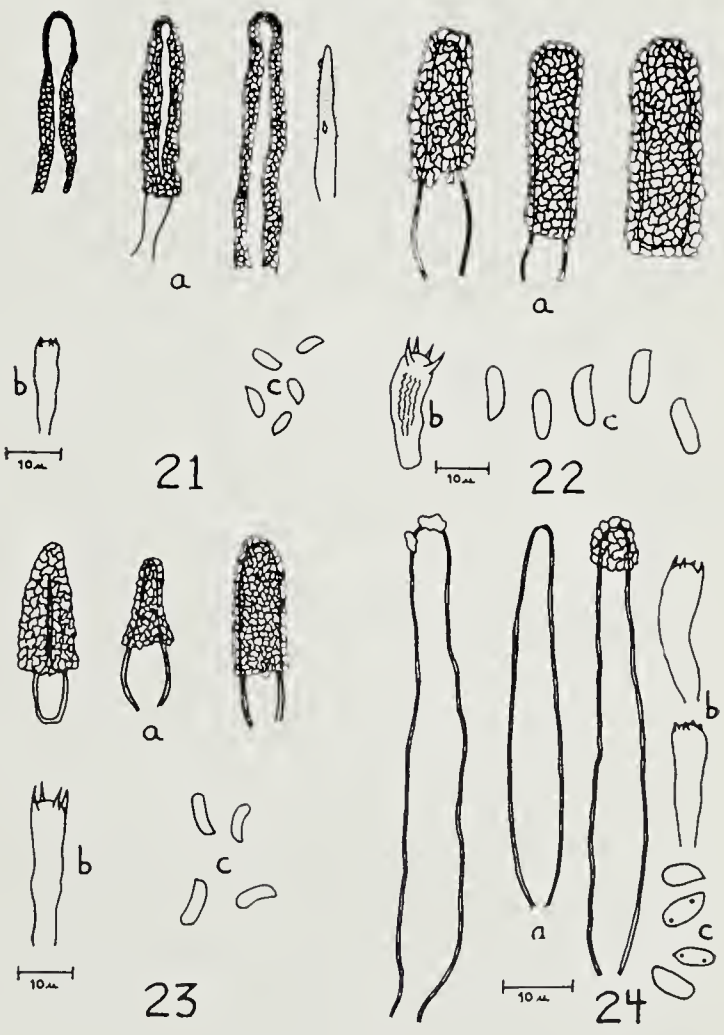
On decayed deciduous wood. Rare in Illinois. Also known from Austria, Canada, Denmark, France, New Zealand, Poland, Sweden, Alabama, Colorado, Idaho, Massachusetts, Michigan, Montana, New Hampshire, New Jersey, New Mexico, New York, Oregon, Pennsylvania, Tennessee, Vermont, Washington, and Wisconsin.

Illinois material examined: Lowden Memorial Park, Oregon VI.6.1964, E. J. Disselhorst & R. J. Harris 66 (RJH).

See discussion under *P. affinis* and *P. coccineo-fulva*.

21. **Peniophora ludoviciana** Burt, Mo. Bot. Gard. Ann. 12:244. 1926. FIGURE 21.

Syn.: *Peniophora flammea* Burt, Mo. Bot. Gard. Ann. 12:252. 1926.



FIGURES 21. *Peniophora ludoviciana.* (a) Four cystidia, one nearly naked; (b) Basidium; (c) Spores. 22. *Peniophora guttulifera.* (a) Three incrusted cystidia; (b) Basidium with resinous contents; (c) Spores. 23. *Peniophora cinerea.* (a) Three incrusted cystidia; (b) Basidium; (c) Spores. 24. *Peniophora cremea.* (a) Three cystidia, two with apical incrustation; (b) Two basidia; (c) Spores, two with small oil droplets.

Fruit body resupinate, widely effused, adnate, subwaxy; surface continuous, verrucose, pruinose, cracking when dry; margin somewhat thinning and whitish; color between Stag (14E7) and Gold (14K7) to Cinnamon Brown (14I10).

Hyphae hyaline, nodose-septate, compact, thin-walled, incrusted, 2-4.5μ in diameter. Cystidia moderate to frequent, mostly immersed, cylindrical-obtuse and heavily incrusted to subfusiform with slight or no incrustation, pseudo-lumen of incrusted cystidia often constricted near the middle, 20-55 x (5-)6.5-9μ. Gloeocystidia absent. Basidia subclavate, bearing 4 sterigmata, 14-20 x 4-4.5(-5)μ. Spores oblong-ellipsoid, flattened on one side, smooth, hyaline, nonamyloid, 3.5-6.5 (-7.5) x 2-3(-3.5)μ.

On decayed deciduous wood. Common, and previously unreported for Illinois. Also known from Bermuda, Canada, Cuba, Alabama, Florida, Louisiana, Michigan, and Texas.

Illinois material examined: west edge of Crab Orchard Lake, near Carbondale, XI.23.1963, A. E. Liberta & R. J. Harris 459 (ISU); next to Mississippi River, Quincy, XI.9.1963, R. J. Harris 27, 28, 43 (RJH).

This species is characterized by its verrucose fructification, constricted pseudo-lumen formed by the heavy incrustation of many of the cylindrical-obtuse cystidia, and short oblong-ellipsoid spores.

22. **Peniophora guttulifera** (Karst.), Sacc. Syll. Fung. 9:240. 1891. FIGURE 22.

Syn.: *Gloeocystidium guttuliferum* Karst., Finl. Nat. Folk Bidr. 48:430. 1889.

Fruit body resupinate, effused, adnate, subwaxy; surface continuous, pruinose, with projecting cystidia resembling upright blunt rice grains; margin indeterminate to often arachnoid; color approaching Maple (11E4), (11E3), or Yellowish (approaching 11F4).

Hyphae hyaline, nodose-septate, difficult to separate, smooth, thin-walled, (2-)2.5-5(-6)μ in diameter. Cystidia few to frequent, broadly cylindrical-obtuse to subclavate when incrusted, broadly subclavate to obclavate when incrustation is removed, slightly thick-walled, (40-)45-70(-90) x (8-)14-20μ. Gloeocystidia absent. Basidia subclavate, bearing 4 sterigmata, contents usually resinous, when young resembling gloeocystidia, 20-30(-35) x 5-7(-9.5)μ. Spores cylindrical, somewhat flattened on one side, smooth, nonamyloid, hyaline, often slightly curved, 8-12(-14) x 3-4.5(-5)μ.

On decayed deciduous wood. Rare, and previously unreported for Illinois. Also known from British Columbia, Denmark, France, Finland, Ontario, Sweden, Alabama, Louisiana, Maine, New Hampshire, New Jersey, Ohio, Oregon, and Vermont.

Illinois material examined: Trelease Woods, Urbana, X.15.1959, A. E. Liberta 173 (AEL).

The large, blunt, incrusted cystidia, along with the large cylindrical spores are distinctive of this species, and help to separate it from other members of *Peniophora*.

23. **Peniophora cinerea** (Fries) Cooke, Grevillea 8:20. 1879. FIGURE 23.

Syn.: *Thelephora cinerea* Fries, Syst. Myc. 1:453. 1821.

(For further synonymy see Burt, 1926, p. 348.)

Fruit body resupinate, at first in small patches which later coalesce and become widely effused, adnate, subwaxy to waxy; surface continuous, pruinose to minutely pilose; margin thin, ending rather abruptly to minutely fibrillose; color Sweetmeat (11C5) to Mauve Blush (12A3).

Hyphae with a brownish tint, nodose-septate, difficult to separate, slightly thick-walled, usually naked, 2.5-4μ in diameter. Cystidia numerous, ranging from obtuse-cylindrical to conical, heavily incrusted, thick-walled, mostly immersed, 15-28(-30) x 5.5-7.5(-9)μ. Gloeocystidia absent. Basidia subclavate, bearing 4 sterigmata, 20-30 x 5-6μ. Spores cylindrical to suballantoid, smooth, hyaline, nonamyloid, (6-)7-9(-10) x 2.5-3μ.

On decayed deciduous wood. Rare in Illinois. Also known from Africa, Australia, Austria, Cuba, Denmark, England, France, Germany, Italy, Jamaica, Japan, Mexico, Newfoundland, New Zealand, Ontario, Puerto Rico, Quebec, Sweden, and most areas of the United States.

Illinois material examined: River Forest, E. T. & S. A. Harper 757 (FH).

P. cinerea is often mistaken for *P. violaceo-livida* or *P. nuda*. The latter two may be separated from *P. cinerea* on the basis of their having gloeocystidia. A careful examination with sulfuric benzaldehyde is required in order to determine the presence or absence of gloeocystidia in specimens thought to be *P. cinerea*.

24. **Peniophora cremea** (Bres.) Sacc. & Syd., Syll. Fung. 16:195. 1902. FIGURE 24.

Syn.: *Corticium cremeum* Bres., Fungi Trident. 2:63. 1898.

Peniophora Eichleriana (Bres.) Bourd. & Galz., Soc. Mycol. Fr. Bul. 28:397. 1913.

Peniophora arachnoidea Burt, Mo. Bot. Gard. Ann. 12:220. 1926.

(For further synonymy see Rogers & Jackson, 1943, p. 314.)

Fruit body resupinate, widely effused, adnate, submembranous; surface continuous, sparsely cracking and exposing the shiny, white, loosely interwoven mycelial strands of the subiculum, minutely pilose, with some areas appearing crystalline because of many cystidia reflecting the light; margin narrow, arachnoid, and white; color between Leghorn (10D3) and Nankeen (10F3).

Hyphae hyaline, simple-septate, loosely arranged and frequently branching in the subiculum, becoming compact in the hymenium, thick-walled, incrusted with small crystals, 4.5-7μ in diameter. Cystidia numerous, cylindrical, tapering gradually into an obtuse or sometimes slightly attenuated apex, narrowing at the base, thin to slightly thick-walled, bearing coarse crystals at the apex, other cystidia finely incrusted or not incrusted, 45-80(-100) x (5-)6-8.5μ. Gloeocystidia absent. Basidia subclavate, slightly emergent, bearing 4 sterigmata, 15-25(-30) x 4.5-7μ. Spores oblong-ellipsoid, smooth, hyaline, nonamyloid, (5-)5.5-8 x 2.5-4μ.

On decayed deciduous wood. Previously unreported for Illinois. Also known from Australia, Austria, Canada, Denmark, England, France, Germany, Japan, New Zealand, Poland, South Africa, Sweden, Alabama, California, District of Columbia, Idaho, Louisiana, Massachusetts, Michigan, Montana, New Hampshire, New Jersey, New York, Oregon, Vermont, and Washington.

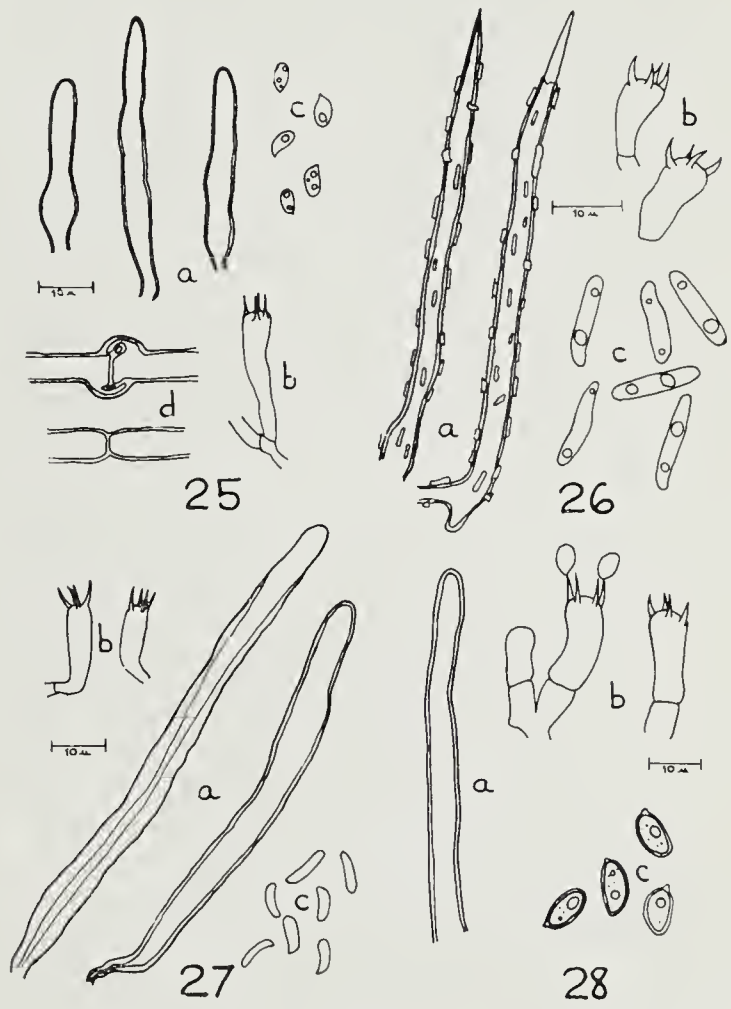
Illinois material examined: Fox Ridge State Park, Charleston, X.5.1963, R. J. Harris 488 (ISU), 13 (RJH).

P. cremea is characterized by its creamy fructification, cracking surface which exposes the white, loosely arranged, branching mycelial strands of the subiculum. The coarsely incrusted obtuse tips of the cylindrical cystidia, when present, are distinctive of this species.

25. **Peniophora burtii** Romell, Burt, Mo. Bot. Gard. Ann. 12:278. 1926. FIGURE 25.

Fruit body resupinate, widely effused, separable, pelliculose; surface continuous, minutely pilose, sometimes flaking away and revealing the large mycelial strands of the subiculum, cracking when dry; margin fibrillose to rhizomorphic, rhizomorphs usually yellow and connecting adjacent fructifications; color between Cream (9D2) and Pinard Yellow (9J2) to Leghorn (10D3).

Hyphae hyaline, simple-septate, with an occasional double clamp connection, often constricted at the septa, loosely



FIGURES 25. *Peniophora burtii.* (a) Three cystidia; (b) Basidium; (c) Spores with droppy contents; (d) Two sections of hyphae showing double clamp connection and constricted septum. 26. *Peniophora longispora.* (a) Two cystidia, one with outer sheath missing at the apex; (b) Two basidia; (c) Spores with two large oil droplets each. 27. *Peniophora subalutacea.* (a) Two cystidia showing variation in wall thickness; (b) Two basidia; (c) Spores. 28. *Peniophora ochroleuca.* (a) Cystidium; (b) Two basidia, one bearing two young basidiospores; (c) Spores with thickened walls and droppy contents.

arranged and somewhat incrusted in the subiculum, becoming compact toward the hymenium, thin to slightly thick-walled, 3-8(-10)μ in diameter. Cystidia rare to frequent, cylindrical-obtuse to subfusiform, hyaline, naked, slightly thick-walled, 30-65 x (3-)5-7μ. Basidia clavate, bearing 4 sterigmata, only slightly stained in KOH-phloxine, 20-30 x 4.5-6μ. Spores varying in shape from broadly ellipsoid to oblong-ellipsoid, somewhat flattened on one side, smooth, hyaline, nonamyloid, 4-6 x 2-3μ.

On decayed deciduous wood. Common, and previously unreported for Illinois. Also known from Alabama, Louisiana, Massachusetts, Michigan, Montana, New Jersey, New York, Ohio, Vermont, Virginia, and West Virginia.

Illinois material examined: Schiller Woods, Schiller Park, VIII.22.1964, R. J. Harris, Sr. & R. J. Harris, Jr. 556 (ISU), 40, 41 (RJH); East Bay Tree Farm, Lake Bloomington, McLean County, X.24.1963, A. E. Liberta & R. J. Harris 42 (RJH).

P. burtii is characterized by its simple-septate hyphae which are constricted at the septa, the yellow rhizomorphs, and the cylindrical-obtuse to subfusiform cystidia.

26. **Peniophora longispora** (Pat.) Höhn., Ann. Mycol. 3:325. 1905. FIGURE 26.

    Syn.: *Hypochnus longisporus* Pat., Jour. de Bot. 8:221. 1894.

    Kneiffia longispora (Pat.) Bres., Ann. Mycol. 1:105. 1903.

    Peniophora asperipilata Burt, Mo. Bot. Gard. Ann. 12:230. 1926.

Fruit body resupinate, widely effused, separable, floccose; surface discontinuous, pubescent to pilose; margin somewhat thinning; color mainly Whitish Grey (11A1), less often Cream (9D2) or approaching Polo Tan (13C6).

Hyphae hyaline, nodose-septate, loosely arranged, thin to slightly thick-walled, somewhat incrusted with small crystals or not incrusted, 2-3.5μ in diameter. Cystidia occurring frequently, cylindrical, usually tapering into a pointed apex, often broken at the tip, sparsely incrusted with rectangular to anvil shaped crystals, covered by an outer sheath which often breaks away revealing the inner, thin-walled cystidium, (40-)50-90 x 2.5-4.5(-5)μ. Gloeocystidia absent. Basidia short-clavate, 13-20(-30) x 4.5-6(-8)μ, bearing 4 sterigmata up to 5μ long. Spores long cylindrical to subfusiform, usually with two large oil droplets, smooth, hyaline, nonamyloid, sometimes crooked at the apiculus end, 10-16 x (1.2-)1.5-3μ.

On decayed deciduous wood. Very common throughout Illinois. Also known from Africa, Australia, Austria, Cuba, Denmark, England, France, Grenada, Jamaica, New Zealand, Ontario, Poland, Sweden, West Indies, Florida, Idaho, Louisiana, Maine, Montana, New York, and Washington.

Illinois material examined: Funk's Grove, McLean County, VI.23.1962, A. E. Liberta 247, 254 (ISU); IX.21.1963, A. E. Liberta & R. J. Harris 8 (RJH); west edge of Crab Orchard Lake, XI.23.1963, A. E. Liberta & R. J. Harris 4, 33 (RJH); White Pines State Park, Oregon, VI.6.1964, E. J. Disselhorst & R. J. Harris 34 (RJH).

This species is well characterized by the long, tapering cylindrical cystidia, sparsely incrusted with rectangular crystals, and the long cylindrical to subfusiform spores.

27. **Peniophora subalutacea** (Karst.) Höehn. and Litsch., K. Akad. Wiss. Wien Math.-Nat. Kl. Sitzungsb. 115(Abt. 1):1601. 1906. FIGURE 27.

    Syn.: *Corticium subalutaceum* Karst., Soc. Faun. Fl. Fenn. Medd. 9:65. 1883.

Fruit body resupinate, effused, adnate, membranous; surface discontinuous and often appearing somewhat porous, reticulate, hirsute in profile; margin indeterminate to very thin; color yellowish tan to approximately Yellow Stone (12K6).

Hyphae hyaline, nodose-septate, loosely interwoven, thin to slightly thick-walled in the subiculum, naked, 2-3μ in diameter. Cystidia occurring frequently, cylindrical-obtuse, sharply tapering near the base, naked, thick-walled, walls thickest at the base and thinning toward the apex, 55-125 x 5.5-8μ. Basidia cylindrical to subclavate, often distorted in KOH mount, 12.5-20 x 3.5-5.5(-6)μ, bearing 4 sterigmata up to 7μ long. Spores narrowly cylindric, smooth, hyaline, nonamyloid, usually slightly curved at the apiculus end, sterigmata often adhering to the apiculus of the free spore, 6-9 x 1.5-2μ.

On decayed deciduous wood. Common, and previously unreported for Illinois. Also known from Austria, British Columbia, Denmark, England, Finland, France, New Zealand, Ontario, Poland, Sweden, Alabama, Idaho, Louisiana,

Maryland, New Jersey, New York, and Washington.

Illinois material examined: Fox River area, Charleston, V.23.1959, A. E. Liberta 6 (AEL); west edge of Crab Orchard Lake, Carbondale, XI.23.1963, A. E. Liberta & R. J. Harris 559 (ISU), 50, 51 (RJH).

The cystidial walls of *P. subalutacea* appear to vary in the collections studied. One collection showed the walls of the cystidia to be very thick; whereas in another collection the walls were only slightly thickened. Weresub (1961) lists several variations and subspecies for *P. subalutacea*, which may account for the difference noted.

28. **Peniophora ochroleuca** (Bres.) Höhn. & Litsch., Ak. Wiss. Wien, Math.-Nat. Kl., Sitzungsb. 117, I:1107. 1908. FIGURE 28.

Syn.: *Coniophora ochroleuca* Bres. apud Brinkm., Westf. Prov-Ver. Jahresber. 26:130. 1898.
Coniophorella ochroleuca (Bres.) Brinkm., Westf. Prov.-Ver. Jahresber. 44:41. 1916.
Peniophora fusispora sensu Höhn. & Litsch., Ann. Myc. 4:289. 1906.

Fruit body resupinate, in small patches which are connected by mycelial strands, separable, submembranous; surface discontinuous, hypochnoid; margin indeterminate; color whitish or between Cream (9D2) and Yellowish (9H3).

Hyphae hyaline, nodose-septate, with much branching, somewhat thick-walled, usually with many short segments, naked, (4.5-)5-10(-12)μ in diameter. Cystidia cylindrical, tapering slightly into an obtuse apex, walls thick in the stem and thinning somewhat toward the tip, naked, 57-300(-360) x (6-)8-10.5(-12)μ. Gloeocystidia absent. Basidia broadly subclavate, bearing 4 sterigmata, (18-)22-35(-48) x 7-9(-10)μ. Spores broadly fusiform, smooth, hyaline to slightly tinted, thick-walled, apiculate, contents granulose, nonamyloid, 9.5-15(-18) x (4-)5-7.5(-8)μ.

On decayed deciduous wood. Rare, and previously unreported for Illinois. Also known from Canada, France, Germany, Massachusetts, and Oregon.

Illinois material examined: Funk's Grove, McLean County, IX.21.1963, A. E. Liberta 476 (ISU).

P. ochroleuca is distinguished from other species of *Peniophora* by its hypochnoid fructification, large thick-walled cystidia, and large broad-fusiform spores.

29. **Peniophora argillacea** Bres., Fung. Trid. 2:63. 1898. FIGURE 29.

Fruit body resupinate, moderately effused, adnate, submembranous; surface discontinuous, appearing pilose due to the projecting cystidia; margin indeterminate to slightly thin-pruinose; color Moonmist (12A2) to Tansan (12B6).

Hyphae hyaline, nodose-septate, usually short-celled with segments sometimes swollen, thin-walled, naked or with scant incrustation, 3-6.5μ in diameter. Cystidia occurring frequently, more or less obclavate-undulate, naked, thin-walled, 80-120 x (9-)10-16μ. Basidia subclavate, constricted near the apex, bearing 4 sterigmata, contents resinous, (12-)15-25 x 5.5-6.5(-10)μ. Spores broad-ellipsoid to slightly suboval, flattened on one side, often curved at the apiculus end, smooth, hyaline, nonamyloid, 7.5-9.5(-10) x 4-5μ.

Growing with *Platygloea peniophorae* on decayed deciduous wood. Rare, and previously unreported for Illinois. Also known from Austria, Canada, Denmark, France, Sweden, Michigan, and Wisconsin.

Illinois material examined: White Pines State Park, Oregon, VI.6.1964, E. J. Disselhorst & R. J. Harris 52 (RJH).

P. argillacea is easily recognized microscopically by its long, obclavate-undulate cystidia. It is also found to be growing with or on another species of fungus. In the only Illinois collection available, *P. argillacea* was nearly obscured by *Platygloea peniophorae*.

30. **Peniophora sambuci** (Pers.) Burt, Mo. Bot. Gard. Ann. 12:233. 1926. FIGURE 30.

Syn.: *Thelephora Sambuci* Pers., Mycol. Eur. 1:152. 1822.
Corticium Sambuci (Pers.) Fries, Epicr. Syst. Mycol. p. 565. 1838.
Corticium cretaceum (Fries) Cooke ex Sacc., Syll. Fung. 11:128. 1895.
Peniophora Thujae Burt, Mo. Bot. Gard. Ann. 12:236. 1926.
(For further synonymy see Rogers and Jackson, 1943, p. 325.)

Fruit body resupinate, widely effused, somewhat separable, submembranous; surface faintly discontinuous, pruinose to farinose, with some areas thick-arachnoid, rarely cracking; margin thinning out and arachnoid; color white to drying Oyster White (10B1).

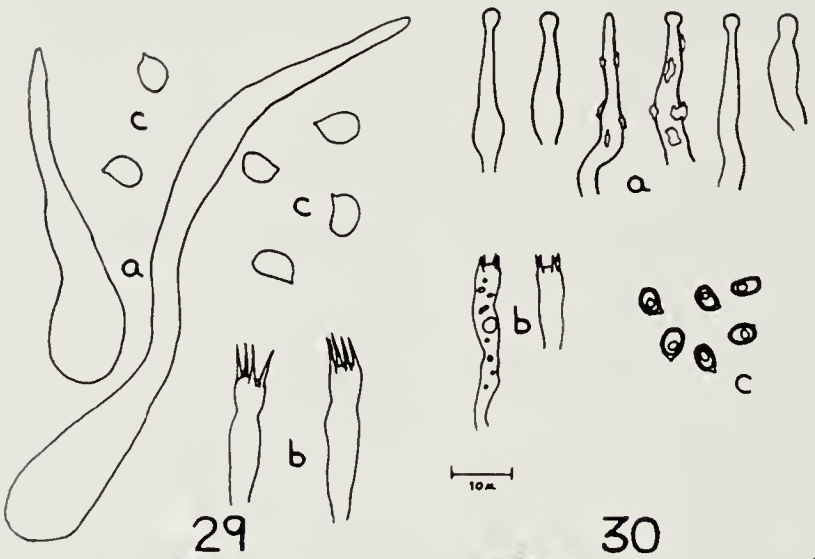
Hyphae hyaline, nodose-septate, naked or sometimes incrusted, with frequent swollen areas, slightly thick-walled, 2.5-

4.5μ in diameter. Cystidia cylindrical-capitate or somewhat tibiiform to subfusiform, thin-walled, mostly naked, occasionally somewhat incrusted, 30-40 (-45) x (3-)3.5-5.5μ. Basidia narrowly clavate, bearing 4 sterigmata, contents droppy, (15-)19-31 x 4.5-5(-6)μ. Spores broadly ellipsoid to occasionally subglobose, hyaline, smooth, nonamyloid, somewhat thick-walled, almost always with one large oil droplet, (4-)6-7(-7.5) x 3-5μ.

On decayed deciduous wood. Common, but previously unreported for Illinois. Also known from Australia, Austria, Belgium, Canada, Denmark, England, France, Germany, Italy, Mexico, New Zealand, Sweden, Ukraine, California, Kansas, Louisiana, Maine, Massachusetts, Michigan, Missouri, New Hampshire, New Jersey, New York, Pennsylvania, Vermont, and Washington.

Illinois material examined: Mississippi River area, Quincy, XI.9.1963, R. J. Harris 491 (ISU), 24 (RJH); Funk's Grove, McLean County, X.28.1963, R. J. Harris 22, 23 (RJH), 490 (ISU).

P. sambuci is easily distinguished from other species of *Peniophora* by means of its somewhat tibiiform cystidia, and somewhat thick-walled, broadly ellipsoid spores containing one large oil droplet.



FIGURES 29. *Peniophora argillacea.* (a) Two cystidia; (b) Two basidia; (c) Spores. 30. *Peniophora sambuci.* (a) Six cystidia, two sparsely incrusted; (b) Two basidia, one with droppy contents; (c) Spores with somewhat thickened walls and a single oil droplet. 31. *Peniophora polonensis.* (a) Two cystidia, one naked and one incrusted; (b) Two basidia; (c) Spores. 32. *Peniophora subtestacea.* (a) Two cystidia, one incrusted and one naked; (b) Two basidia; (c) Spores, one with granular contents.

31. **Peniophora polonensis** (Bres.) Höhn. & Litsch., Ann. Mycol. 4:292. 1906. FIGURE 31.

Syn.: *Kneiffia polonensis* Bres., Ann. Mycol. 1:103. 1903.

Peniophora canadensis Burt, Missouri Bot. Gard. 12:260. 1926.

Fruit body resupinate, effused, separable from the substrate, floccose; surface discontinuous, somewhat hypochnoid, hispid in profile; margin arachnoid; color Yellowish (9G2, 9H2, 9G3, 9H3).

Hyphae hyaline, nodose-septate, thin-walled, naked, 4-5(-6)μ in diameter. Cystidia occurring frequently, long-cylindrical, delicately incrusted to little or no incrustation, thin-walled, septate, often with constrictions and clamp connections at the septa, tapering toward the base, (75-)85-200(-250) x (6-)7-9.5μ. Gloeocystidia absent. Basidia cylindrical to subclavate, usually with a slight constriction near the middle, often arising in a candlebra fashion, (18-)24-28(-30) x (4-)4.5-6μ, bearing 4 sterigmata. Spores oblong-ellipsoid to sub-ovate, smooth, hyaline, nonamyloid, apiculate, 6-8(-9.5) x (3.5-)4-5μ.

On decayed deciduous wood. Rare, and previously unreported for Illinois. Also known from Austria, Denmark, France, Ontario, Poland, Sweden, Connecticut, Michigan, New York, North Carolina, and Pennsylvania.

Illinois material examined: Funk's Grove, McLean County, XI.24.1961, S. F. & A. E. Liberta 565 (AEL).

P. polonensis is characterized by its floccose fructification, oblong-ellipsoid to sub-ovate spores and its delicately granular, large septate cystidia.

32. **Peniophora subtestacea** Litsch., Oesterr. Bot. Zeitschr. 77:132. 1928. FIGURE 32.

Fruit body resupinate, widely effused, adnate, membranous; surface continuous with sparse cracking, hirsute; margin ending somewhat abruptly to sometimes arachnoid; color Tansan (12B6) to Honeysuckle (12D6).

Hyphae hyaline, nodose-septate, thin-walled, usually naked, difficult to separate, 3-4(-5)μ in diameter. Cystidia occurring frequently, cylindrical, often narrowing abruptly near the base, sparse to heavy incrustation with large crystals, thick-walled, septate, clamp connections often present at the septa, (50-)65-200 x (7-)9-13μ. Gloeocystidia absent. Basidia cylindrical, but often bending into irregular shapes, (15-)20-30(-35) x 5-7μ, bearing (2-)4 sterigmata. Spores cylindrical to oblong-ellipsoid, often appearing flattened on one side to sometimes slightly curved, contents often granulose, smooth, hyaline, nonamyloid, apiculate, (6.5-)8.5-11(-12) x 3.5-4.5μ.

On heartwood of deciduous tree. Rare, and previously unreported for Illinois. Also known from Austria, Ontario, Sweden, Connecticut, Iowa, Massachusetts, New York, Ohio, and Pennsylvania.

Illinois material examined: Funk's Grove, McLean County, V.29.1962, A. E. Liberta 411 (AEL).

P. subtestacea closely resembles *P. aspera*, but differs from the latter in having a darker colored hymenium and in having a hirsute fruit body rather than one that appears somewhat odontoid.

SUMMARY

This study serves as an up-to-date supplement to the previous knowledge of the genus *Peniophora* in Illinois, and provides a useful reference for present and future investigators. It should be noted that it is in no way intended to be a complete monograph of the species. A record of 32 species of *Peniophora* now exists for Illinois, in contrast to the preexisting 8 reported species.

All species described were found on fallen and decaying deciduous wood. Almost all species were found to occur throughout the state. The majority of material collected represents no major range extensions of the species, but helps to fill the existing distribution gaps in the midwest.

A gradual southward range extension of two species, *P. subulata* and *P. argillacea* is indicated in view of the fact that prior to this research these species had only been collected north of Illinois.

Acknowledgments

The author wishes to express his deepest gratitude to Dr. Anthony E. Liberta for his continued encouragement and guidance.

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Manuscript received April 1, 1966.

AKINETES, REPRODUCTION, AND COLONY FORM IN THE GREEN ALGA *SORASTRUM*

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ABSTRACT. — One-month-old cells of *Sorastrum* in a defined mineral medium enlarged slightly and became thick-walled, yellow-green, and packed with yellow fat droplets in which carotenoid pigments were dissolved. These akinetes survived desiccation for at least one month. When placed in a fresh culture medium, they germinated and produced daughter colonies as do vegetative (non-akinete) cells. Reproduction in *Sorastrum* is described, and the author advances an hypothesis to account for colony shape.

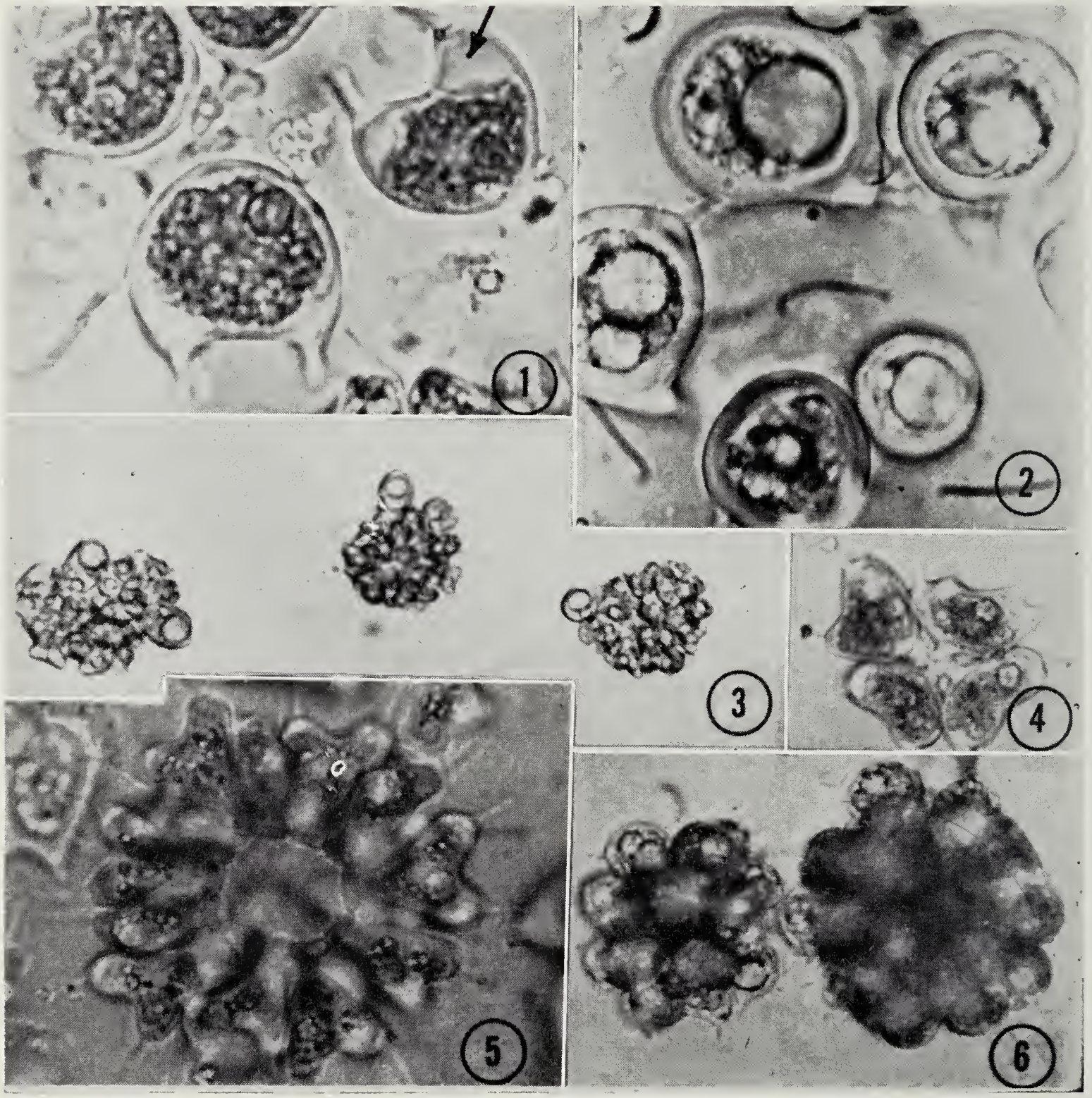
Although reproduction in the colonial green alga *Sorastrum spinulosum* has been described by several workers, their papers give conflicting reports: De-la-Rue (1873) observed that colony cells separate, enlarge, but may become thick-walled cysts. Colony cells usually divided into two parts, each of which became typically shaped cells. With further development these cells became cysts. The contents of the cysts divided into two to several cells which united to form a colony. The colony was released when the cyst wall disappeared or when it broke apart. Palik (1936 also observed the resting stages (cysts) of *Sorastrum spinulosum*. These were thick-walled, yellow cells containing red oil droplets. He demonstrated that the resting stages were able to survive four months of desiccation and freezing temperatures. Probst (1926) stated that during reproduction the cell contents divided into 8-64 multinucleate "plasmaballen" which were released in a vesicle. Each of these divided again and gave rise to groups of 4-32 biflagellate zoospores which became separate colonies. Palik also observed several daughter colonies in one vesicle. Geitler (1924) reported that reproduction begins with the successive division of the chloroplast and of the multinucleate protoplast into parts each of which becomēs a zoospore. The zoospores were released in a vesicle through a break in the wall of the mother cell. Zoospores moved slowly for a while, stopped, flattened, and formed one hollow spherical colony. The colony of zoospores became united at its center. The vesicle disappeared, and each cell of the young colony developed four horns toward the outside and a stipe toward the center of the colony. The stipes of all cells were embedded in a sphere of gelatin.

I have seen the complete process of reproduction many times. I have also obtained cells (akinetes) similar to the cysts of De-la-Rue, and to the yellow, thick-walled cells (resting stages) of Palik. The present study describes my observations of reproduction, colony formation, and akinete formation and germination.

Materials and Methods

A unialgal culture of *Sorastrum* (LB 785) was obtained from the Culture Collection of Algae at Indiana University. The author determined that the alga was *Sorastrum spinulosum* Näg. The culture was used to inoculate five test tubes containing 15 ml of sterile mineral Medium C (Davis, 1963), and four 125 ml Erlenmeyer flasks containing 75 ml of sterile Medium C. The algae in the tubes were subcultured every 10 days; those in the flasks were not subcultured. The cultures were under fluorescent "cool white" lights of 350 ftC with a 16/8 hour light/dark cycle. Temperature was maintained at 20± 2 C. Nuclear staining was done with hematoxylin stain prepared and used according to Bowen (1963).

Reproduction and colony form in vegetative cells—Colonies from the ten-day-old culture were transferred to the fresh culture medium. After one or two days the uninucleate protoplasts divided in many planes so that the cell contents were progressively cleaved into many



Figures 1-6. — Cells and colonies of *Sorastrum spinulosum*. 1. Ten-day-old cells; arrow is in body at base of horns; 900X. 2. Thick-walled akinetes containing fat droplets, 900X. 3. Daughter colonies from akinetes; projecting cells contain fat droplets. 4. A 4-celled colony with solid center. 5. Hollow-centered 32-celled colony. 6. Colonies of akinetes. (3-6, 450X).

small parts. The nucleus of such cells also divided so that each of these small parts contained one nucleus. The small parts separated and became rounded zoospores. Cells containing such zoospores were spherical and considerably larger than cells not forming zoospores. After one to three days the outer wall of the mother cell cracked in several places and the thick middle wall adjacent to the cracks disappeared. Then the outer wall split off, the middle wall disappeared completely, and the zoospores were left in a hyaline vesicle. Before the outer wall split off, the vesicle was the innermost layer of the cell wall. Occasionally the vesicle was extruded through a wide crack in the outer wall, and the outer wall with its horns and stipe did not break apart. Usually 16 or 32 zoospores were in each vesicle, occasionally eight. Each zoospore was spherical with two flagella, and contained a parietal chloroplast which occupied the entire contents except for a small clear portion from which the flagella emerged. Just after release the vesicle was the same size as the mother cell, and the confined zoospores began to wriggle slowly within it. The vesicle then expanded slowly as the zoospores moved faster and arranged themselves in a spherical colony one cell thick and in contact with the vesicle. After moving for 3-5 minutes, the zoospores slowed down and stopped. The clear parts of the zoospores with the flagella pointed toward the center of the colony. Each zoospore produced a stipe toward the center of the colony and four horns toward the outside. The stipes were produced by the clear part of the zoospore; the horns grew from the wall adjacent to the chloroplast. Stipe and horn formation began a few seconds after the zoospores stopped moving and was completed in three to five minutes. In four and eight-celled colonies the stipes grew together and filled the center of the originally hollow colony (Fig. 4). In sixteen and thirty-two-celled colonies, and in some eight-celled colonies, the base of the stipes broadened slightly into disks parallel to the colony surface (as in Fig. 5). The disks of neighboring zoospores grew together and fused. Just after fusion each disk was hexagonal. The bases of the stipes thus formed a hollow central sphere bounded by the hexagonal disks. Except in aberrant colonies, the vesicle expanded so that the young colony floated free within it. These events (protoplast cleavage through vesicle expansion) occurred within one day. The vesicle disappeared after one or two more days, and the young colony reached full size (35-40μ dia) in ten to fifteen days. Cells of ten-day-old colonies contained a large central vacuole completely surrounded by a parietal chloroplast, one nucleus, and a single pyrenoid. Neither the nucleus nor the pyrenoid occupied a fixed location.

Each cell had two pairs of horns. Often each mature cell contained one or two solid, clear, lenticular bodies (approx. 6X8μ) at the bases of the pairs of horns (Fig. 1). Frequently the body under one pair of horns of a cell was considerably larger than that under the other pair. After the release of the vesicle these bodies usually remained attached to the outer surface of the vesicle, or they remained in place attached to the remnants of the mother cell. An aqueous solution of anilin blue stained these bodies blue, thus indicating they were of callose (Johansen, 1940, p. 185).

Some ten-day-old cells and all older cells developed a thick middle wall between the vesicle and the outer cell wall. The pectin stain ruthenium red (Meyer, Anderson & Swanson, 1955, pp 165-166) colored the thick middle walls red; the cellulose stain chloroiodide of zinc (Sass, 1958, p 97) colored them blue. An aqueous methylene blue solution (recommended by Bold, 1957, p 630, for algal sheath staining) colored them blue, and stained the inner layers most deeply. This stain failed to reveal any gelatin in the center of the colony.

There were a few aberrant colonies on almost every slide prepared for observation. These colonies always occurred in a constricted space: either the vesicle failed to expand, or it failed to be released and thus the colony formed within the mother cell. Zoospores forming these aberrant colonies did not move. Zoospores of such colonies usually formed fewer than four horns, and generally not all of the horns projected toward the outside of the spherical colony. These zoospores, however, did produce stipes.

Multiple colonies were observed within a vesicle on three different occasions. Two 16-celled colonies in one vesicle were observed twice. Another vesicle contained 4 colonies; two 8-celled and two 16-celled. All these colonies and their cells were typically shaped.

Akinete formation—Algae in the flasks formed akinetes. After inoculation and reproduction, these algae grew to full

size in about ten days. Very little reproduction occurred thereafter. During the next 20 days each cell gradually deposited a thick middle wall of several layers. In addition, a clear, solid, lenticular body formed between the middle wall and the inner wall on each side of the cell at the bases of the pairs of horns.

As the thick middle wall was deposited, the cells became almost spherical and somewhat larger than ordinary cells. At the end of the third week in the culture medium, many small yellow droplets appeared in the cells. In one more week these became larger and coalesced to form 2 or 3 large droplets (Fig. 2). After the cells had developed their thick middle walls, a slight pressure on the coverslip would separate the cells of a colony. By the end of the fourth week the mass of colonies was yellow-green. Except for color, the individual colonies looked like ordinary vegetative colonies (Fig. 6). The culture solution was decanted at the end of the fourth week and the colonies, now akinetes, were allowed to dry completely. When dry, they were a bright orange. Dry colonies and cells shrank slightly, but otherwise did not change their shape. Most of the cells contained one nucleus; a few contained 2 or more nuclei.

After several months in the culture solution, the akinetes became orange and enlarged slightly. Some of the akinetes enlarged markedly to become almost twice the diameter of vegetative cells.

The akinetes reacted to stains like vegetative cells. The orange droplets within the akinetes were fat colored by carotenoid pigments, for when concentrated H_2SO_4 was dropped on akinetes the orange droplets became light blue. After removal of the acid and treatment with Sudan IV, the droplets became red, thus demonstrating that they were of fat. Evidence of the presence of carotenoid pigments is given by the change of color from orange to light blue with the treatment of sulfuric acid (Johansen, 1940, p 201). This is further supported by using ethyl ether to obtain a yellow extract from the akinetes, which extract, when placed in a DU spectrophotometer gave an absorption curve displaying in the visible spectrum a single maximum at 470 mμ.

Akinete germination — A small quantity of akinetes which had been dry for one month was placed in fresh Medium C. These akinetes became green in one day, and in two to three more days they produced daughter colonies in the same manner as vegetative cells. Colonies formed from akinetes, however, often contained large, fat-filled cells (Fig. 2). As an akinete formed zoospores, its fat droplets were incorporated into one to several zoospores. Zoospores containing fat droplets were larger and moved more slowly than those formed from zoospores without droplets. Most cells containing droplets failed to form all four horns; some formed no horns at all.

Discussion

Although Probst (1926) observed that *Sorastrum* in solutions whose mineral concentration was over 0.3% produced thick-walled cells, he reported that such cells would degenerate unless soon transferred to a suitable medium. Thus he may have observed akinetes without recognizing them as such.

Akinetes and old vegetative cells have three distinct walls: the innermost wall which becomes the vesicle; the thick middle wall which has a lamellar construction; and the outside wall, parts of which form the horns and stipes. Probst, (1926) using congo red stain, deduced that the outside wall of the mother cell and the stipes were cellulose. He assumed that the middle wall contained pectin since congo red did not stain it. In my work, the thick middle wall of akinetes and the thick middle wall of vegetative cells reacted to the strains for cellulose, pectin, and gelatin (methylene blue). Since the middle wall quickly dissolved after the outer wall broke away, it is not cellulose, but more likely a combination of pectin and gelatin, as both of these are water soluble. West (1916, p. 127) stated that the gelatinous substances of

algal cell walls stain with both methylene blue and ruthenium red.

Those zoospores produced from akinetes and containing fat droplets often failed to produce all four horns. Such zoospores were larger and less active than the other zoospores in the same vesicle. If we accept with Geitler (1924) that all cells are polar, then the horn forming parts of such slow moving zoospores might become disposed against another cell and thus unable to form all four horns. A similar phenomenon occurred in *Pediastrum* (Davis, 1962).

Although Probst (1926) and Palik mention multiple colonies in one vesicle, such colonies were not mentioned in Geitler's report nor did I observe more than three vesicles containing multiple colonies. I also did not observe the central sphere of gelatin mentioned by Geitler (1924). However, my observations of reproduction agree essentially with those of Geitler (1924) and Probst (1916).

It is possible that all colonies observed by Probst (1926) and De-la-Rue were similar to the aberrant ones described in this study. Observations of colonies confined within the mother cell may account for De-la-Rue's failure to observe zoospores. The "plasmaballen" mentioned by Probst could have been zoospores in non-expanding vesicles each of which later developed into a colony.

Generally, large colonies were hollow while small colonies had solid centers. This is to be expected as zoospores of four and eight-celled colonies are close enough for their stipes to join at the center. This union probably occurred before the stipes reached full length and thus inhibited the formation of the disks observed in the 16 and 32-celled colonies. In these larger colonies, the stipes of the single layered colony were too short to join at the center of the colony. In such colonies, the stipes grew to full length and developed disks which joined and became hexagonally shaped from mutual pressure. *Sorastrum americanum* also produces a similar hollow central sphere made of the hexagonal bases of the stipes (Fritsch, 1935, p. 170, 49B after Schröder).

Probst (1916, 1926), Palik (1936), and the present author have observed two flagella on each zoospore. All three authors have noted that the flagellar end of the zoospores turned toward the center during colony formation while the opposite end formed the horns. Probst (1926) and the present author further agree that the flagella occurred at a clear portion of the zoospore wall and that this clear portion produced the stipes.

Davis (1964) and Moner (1953) have observed that the colonies of *Pediastrum* are formed in a lens-shaped vesicle and are flat. As is well known, the colonies of *Sorastrum* are formed in a spherical vesicle and are spherical. Pocock (1960) notes that when *Hydrodictyon reticulatum* reproduces asexually, the new colonies form in the narrow cylindrical space between the outer wall and the vacuolar membrane and are cylindrical. Bonner (1963, pp. 156-159) argues that the shape of such asexually produced colonies of *H. reticulatum* is determined by the shape of the mother cell, and his argument may be applied with only minor changes to *Pediastrum* and

Sorastrum. Thus the colony shape for these genera of the Hydrodictyaceae would seem to be determined by the shape of the mother cell or the vesicle at the time the colony is forming.

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Manuscript received March 10, 1966.

BURGNER ACRES NATURAL AREA OF EASTERN ILLINOIS UNIVERSITY

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ABSTRACT. — A preliminary survey of a forest, Burgner Acres Natural Area, Coles County, Illinois, was made in 1955, and the trees and shrubs in six permanent quadrats of 100 square meters each were studied in some detail. In 1962, the six quadrats were re-examined and in addition over 1700 trees encountered along six line transects were identified and evaluated as to their relative dominance and frequence.

On January 29, 1955, Eastern Illinois University received its first land gift which has become known as Burgner Acres. This ten acre tract of forested land was presented to Eastern by Mrs. Helen Burgner Douglas as a memorial to her father and grandparents who were pioneer settlers in Coles County. The forest is located approximately 8 miles Northwest of Eastern Illinois University campus in Lafayette Township of Coles County (FIG. 1).

The tract is approximately 1300 feet long and 338 feet wide. It is described as the E. ½ of the W. ½ of the S.W. ¼ of the N.E. Qt. Section, Twsp. 12N. Range 8E. Its isolated relationship to the surrounding farm area is shown well by an aerial photograph (FIG. 2).

PLANT ECOLOGY STUDIES AT BURGNER ACRES

The Burgner Acres Forest is divided into three rather well defined study areas by Sycamore Creek which winds across the north end from west to east and then returns on the south end to flow from east to west (FIG. 3). The portion from the entrance to the stream is known as Area A and, until 1954, a sizeable area was mowed and maintained in park-like fashion. The portion of the forest betwen the stream channels is referred to as Area B and the remaining forest on the extreme south end beyond Sycamore Creek is called Area C. Plants have been observed and data collected since the spring of 1955. Six permanent quadrats of 100 square meters each were established in 1955 and were re-examined in 1962. Locations of the

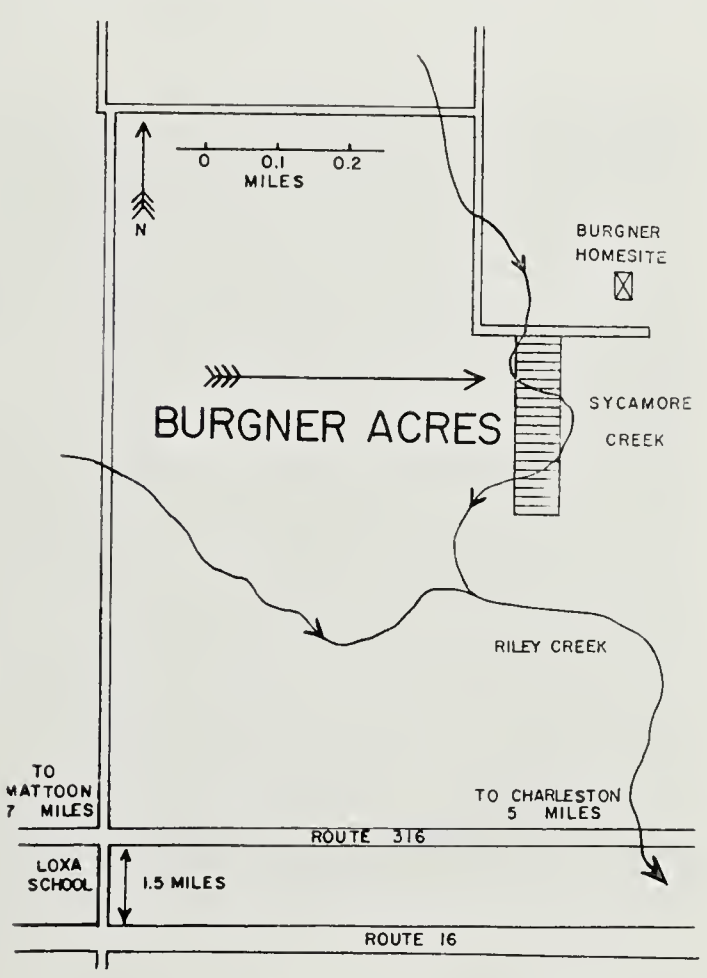

FIGURE 1. — Location Map of the Burgner Acres Natural Area.

permanent quadrats in the three areas are shown in FIGURE 3. Six line transects, approximately 50 feet apart, involving over 1700 trees were made in April, 1962. Observations relative to these studies follow (Henderson, 1962).

AREA A. — This area illustrates what happens to abandoned land in Eastern Illinois when left to go back to nature. In 1955, Quadrat 1 was a grass covered plot of 100 square meters. It remained in grass for the same reason that most pastures remain in grass in this area, namely, the continuous clipping by animals. However, in this case, it was man with his mechanical clipper, or the mower. In 1962, or seven years after mowing ceased, there were 68 trees found growing in this same quadrat. Red elm was most abundant with 51 specimens followed with 10 hickory, 5 hawthorn, and 2 walnut. This evidence would seem to support the theory that most abandoned land in East Central Illinois would more than likely return to a forest type of vegetation rather than a grassland or prairie type (Damann, 1955).

Much of Area A was not mowed and along the stream there exists a typical flood plain type of forest vegetation. A total of 539 trees was counted over the entire Area A. This number resulted from a random sampling of the area by walking transect and does not imply that there were only 539 trees present. Each tree was named and size or basal area occupied by the tree was deter-

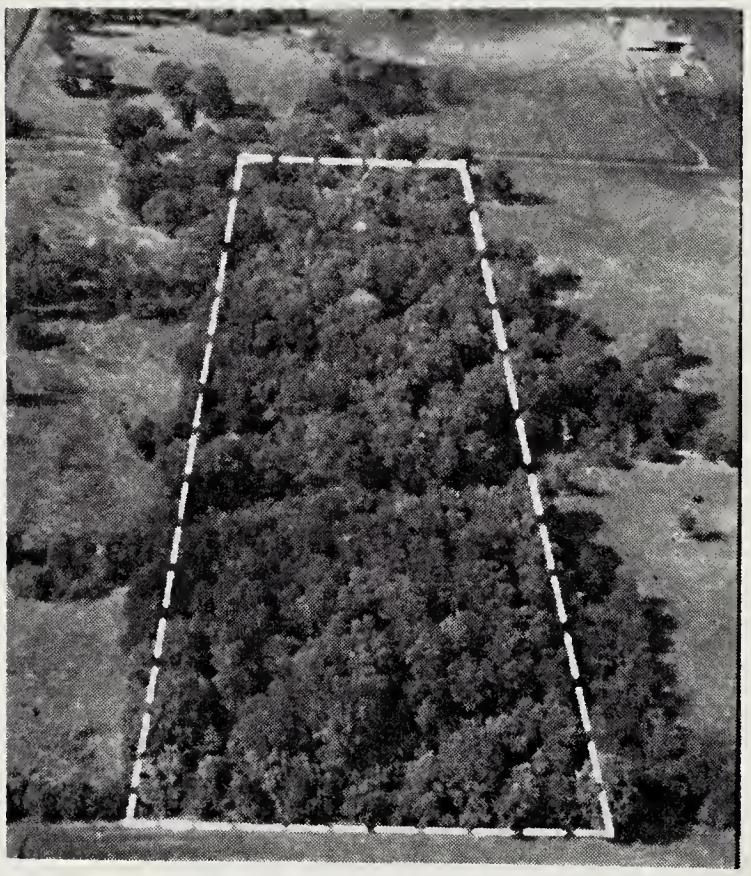

FIGURE 2. — Aerial Photograph of Burgner Acres. Note pastured and cultivated land surrounding the narrow strip of forest.

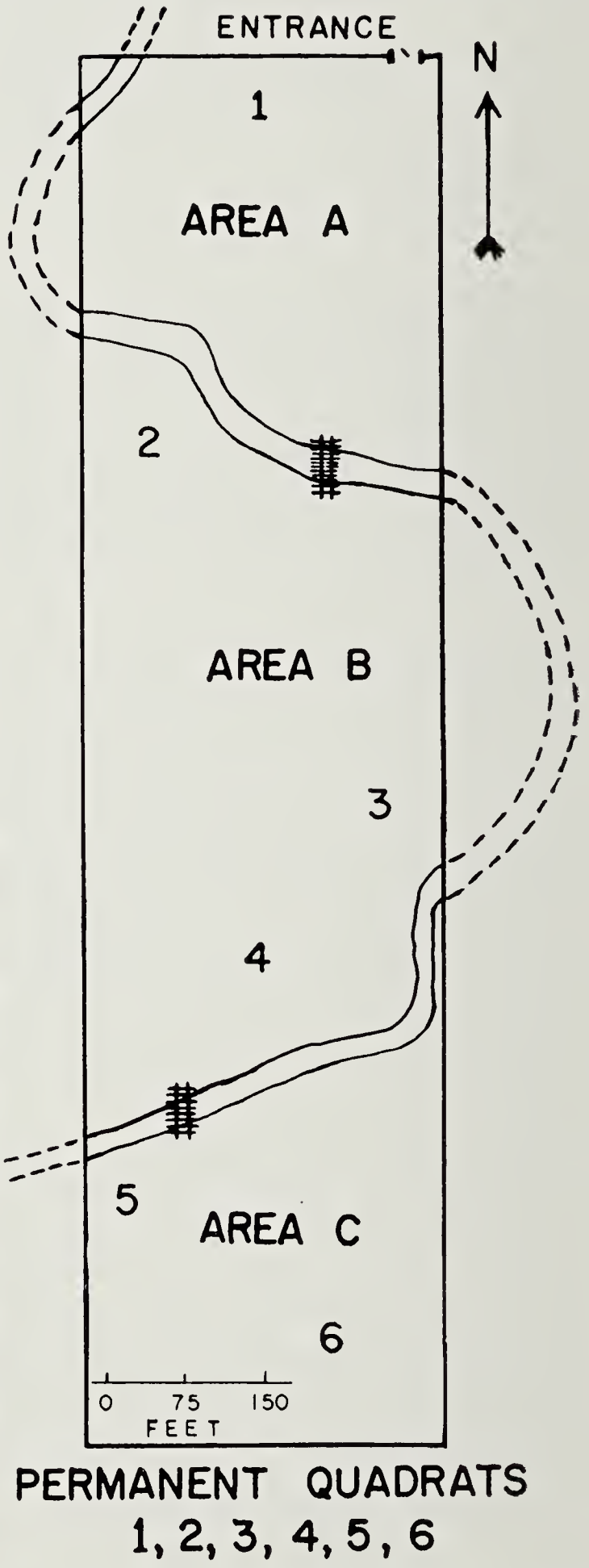

FIGURE 3. — Location Map of Permanent Quadrats in Areas A, B, and C of Burgner Acres.

mined. The results are expressed as both the relative percent of total number counted and also the percent of basal area occupied by each tree. Fifteen different tree species were encountered in the random count of Area A. Twenty species were encountered in the entire forest; they have been arranged alphabetically in TABLE 1 for comparison of their occurrence in the three study areas. It should be noted that ash, hackberry, red elm, shagbark hickory, and hawthorn occupied 88 percent of the basal area and thus would be considered the five dominant trees in Area A (TABLE 2).

AREA B.—The least disturbed portion of the forest lies between the two creek channels and has been designated as Area B (FIG. 3). A total of 667 trees was encountered in six line transects with ash, shagbark hickory, red elm, bitternut hickory, and hackberry occupying 84 percent of the total basal area (TABLE 2). Other trees present in order of decreasing basal area were red oak, osage orange, sycamore, crab apple, hawthorn, black cherry, black haw, white mulberry, black locust, honey locust, and wahoo (TABLE 1).

Three permanent Quadrats (2, 3, and 4) are located in Area B. Quadrat 2 had 84 trees present in 1962, with 39 being ash. Unfortunately, the tree count data for 1955 was not completed because of a more detailed analysis made of herbs and shrubs present.

Quadrat 3 is located near the east border of the forest on a gentle slope and had 55 trees of all sizes present in 1955. In 1962, 139 trees were found in the same area. The marked increase was due mainly to seedling trees, less than 1 inch in diameter, of ash, elm, and hickory. Ash trees increased from 20 to 50 and elm from 12 to 42 between 1955 and 1962.

Quadrat 4 is located on rich bottom land or flood plain in a more mature part of the forest. Only 38 trees were

TABLE 1.—Summary of Tree Count made in the Three Areas of Burgner Acres, April 16, 1962.

Tree Species	Area A		Area B		Area C	
	Percent of Number	Percent Basal Area	Percent of Number	Percent Basal Area	Percent of Number	Percent Basal Area
Acer saccharum (Sugar Maple)	3.3	0.2	.....	.....	4.4	0.1
Carya ovata (Shagbark Hickory)	6.3	13.4	11.8	24.7	8.0	17.7
Carya cordiformis (Bitternut H.)	.....	.....	4.5	9.7	1.5	0.1
Celtis occidentalis (Hackberry)	30.2	17.3	14.2	7.6	7.4	8.1
Cercis canadensis (Redbud)	.....	.....	.....	.....	0.6	0.6
Crataegus spp. (Hawthorn)	5.9	6.5	5.5	0.9	.....	.....
Euonymus atropurpureus (Wahoo)	0.4	0.01	2.4	0.1	0.6	0.1
Fraxinus americana (White Ash)	14.0	35.8	23.5	27.9	45.4	17.1
Gleditsia triacanthos (Honey Locust)	0.7	0.4	0.4	0.1	1.5	2.7
Juglans nigra (Black Walnut)	1.1	5.1	.....	.....	.....	.....
Maclura pomifera (Osage Orange)	.....	.....	1.3	2.6	0.2	4.0
Malus ioensis (Crab Apple)	8.7	2.2	4.2	1.0	3.3	0.5
Morus alba (White Mulberry)	3.1	0.5	0.6	0.1	.....	.....
Platanus occidentalis (Sycamore)	.....	.....	0.3	2.1	.....	.....
Prunus serotina (Black Cherry)	1.1	0.03	4.2	0.5	0.6	0.8
Quercus alba (White Oak)	2.6	2.3	1.0	2.1	4.0	45.5
Quercus rubra (Red Oak)	.....	.....	2.1	7.0	.....	.....
Robinia pseudoacacia (Black Locust)	0.7	0.8	0.1	0.1	.....	.....
Ulmus rubra (Red Elm)	21.1	15.4	19.5	12.8	17.6	2.2
Viburnum prunifolium (Black Haw)	0.7	0.02	4.0	0.2	4.7	0.4
Total Number of Trees Sampled	539		667		522	
Total Basal Area (Square Inches)		4,973		11,371		9,480

found in this 100 square meter area in 1955, and this number decreased to 28 in 1962. The tree that decreased the most was hackberry which showed a loss of 15 specimens to 6. A large bur oak produces dense shade on this Quadrat and this undoubtedly has a marked effect upon seedling production and survival. Several extremely hot and dry summers might also have contributed to the decrease of hackberry (Henderson, 1962).

AREA C. — This portion of Burgner Acres is occupied by a forest type typical of many of the upland forests in East Central Illinois in which the dominants are white oak and hickory. A total of 522 trees was sampled with white oak, shagbark hickory, white ash, hackberry, and osage orange occupying 93 percent of the basal area (TABLE 2). Other trees in the order of their decreasing basal area were honey locust, red elm, black cherry, redbud, crab apple, black haw, bitternut hickory, sugar maple, and wahoo (TABLE 1).

Two permanent quadrats are located in this area. Quadrat 5 is on the west border of the forest on a slope that faces to north adjacent to Sycamore Creek (FIG. 3). In 1955, it had 92 trees present and the number increased to 136 in 1962. This increase was due almost entirely to sugar maple reproduction. Young maple trees increased from 55 to 90.

Quadrat 6 is on the level upland near the southeast corner of the forest (FIG. 3). It had only 54 trees in 1955, and that number decreased to 46 in 1962. Hackberry, bitternut hickory, and oaks showed decreases in this area.

LARGE SPECIMEN TREES

A large black haw (*Viburnum prunifolium*) growing near the entrance to the forest in Area A was declared the State of Illinois Champion Black Haw Viburnum in the Big Tree Project of the United States sponsored by the American Forestry Association (Besley, 1955). This specimen of black haw, when measured by the plant ecology class on May 3, 1955, was found to have a circumference of 1'11" at 3 feet height. Standard measurements are made at breast height of 4 feet. However, since this specimen branches at about this point, it was necessary to measure at a lower level for a full trunk measurement. Maximum height was 21'10" with a spread of over 23 feet. On July 25, 1965, the circumference was 2'1", showing a growth of 2 inches in circumference in eleven years.

The diameters of the other larger trees encountered in April of 1954 were:

Ulmus rubra, red elm, 52 in.
Celtis occidentalis, hackberry, 33.5 in.
Maclura pomifera, osage orange, 33.5 in.
Platanus occidentalis, sycamore, 33 in.
Quercus macrocarpa, bur oak, 33 in.
Quercus alba, white oak, 27.5 in.
Juglans nigra, black walnut, 25.5 in.
Fraxinus americana, white ash, 22 in.
Carya ovata, shagbark hickory, 22 in.
Carya cordiformis, bitternut hickory, 20 in.
Quercus muhlenbergii, chestnut oak, 19 in.
Crataegus mollis, hawthorn, 13 in.

DISCUSSION AND SUMMARY

A comparison of the dominant trees in the Burgner Acres forest comprises TABLE 2. This summary is based upon 1728 trees encountered on April 16, 1962, along six line transects. White ash was found to occupy the highest percentage of basal area in both study regions A and B. Hackberry ranked second to white ash in Area A with red elm and shagbark hickory a very close third and fourth based on their relative dominance. However, with 51 percent of the species encountered in Area A being hackberry and red elm, it would appear that this portion of the Burgner Acres is a rather typical mesic flood plain forest.

The terrain of Area B shows the most variation in topography with an increase of elevation ranging from approximately 20 to 40 feet on the north end. There is a gentle slope facing to the south back to flood plain level where this area is bounded by Sycamore Creek. In this area, shagbark hickory occupied essentially the same basal area as white

ash followed by red elm, bitternut hickory and hackberry, respectively. The oaks failed to rank within the first five species. White oak occupied 2.1 percent and red oak 7.0 percent of the basal area. When combined these two species would rank fifth above hackberry. Thus, this forest type would appear to be moving toward elm-ash-hackberry complex in competition with shagbark and bitternut hickory.

The extreme south end of the forest (Area C) appears to be a white oak and shagbark hickory association with these two species occupying 64 percent of the basal area. Only 12 percent of the trees encountered in this area were oak and hickory, which indicates the specimens encountered were quite large. White ash ranked third in basal area, but 45 percent of the species encountered were white ash. Red elm and hackberry accounted for 25 percent of trees encountered. Thus, with 70 percent of trees counted being either elm, ash, or hackberry, the data would seem to indicate that the oak-hickory association would be replaced eventually by the more mesic elm-ash-hackberry complex with a good possibility that sugar maple will gain significantly in importance. This is evidenced by the increase of maples in Quadrat 5 from 55 to 90 specimens between 1955 and 1962.

A more comprehensive and detailed study of the woody vegetation of Burgner Acres has been completed by Blackmore and Ebinger (1964-65) and is being prepared for publication. Unpublished data, not cited but pertinent to Burgner Acres, on file at Eastern Illinois University are: Brown, K. (1955) Floristic study of Burgner Acres; Jones, W. (1962) Bird nesting study of Burgner Acres; Peterka, H. E. (1964-66) Study of bird populations in Burgner Acres; and Poorman, A. (1959) Winter population of birds and mammals of Burgner Acres.

TABLE 2.—Comparison of Relative Frequency Determined by Percent of 1728 Trees Encountered and Relative Dominance Determined by Basal Area Occupied in Burgner Acres Forest on April 16, 1962.

Area A			Area B			Area C		
Species	Relative Frequency %	Basal Area %	Species	Relative Frequency %	Basal Area %	Species	Relative Frequency %	Basal Area %
White Ash.....	14	36	White Ash...	24	28	White Oak...	4	46
Hackberry.....	30	17	Shagbark....	12	25	Shagbark....	8	18
Red Elm.....	21	15	Red Elm....	20	13	White Ash...	45	17
Shagbark.....	6	13	Bitternut....	5	10	Hackberry...	7	8
Hawthorn.....	6	7	Hackberry...	14	8	Osage Orange	1	4
Totals.....	77	88		75	84		65	93

Acknowledgments

The authors are grateful to the members of the Plant Ecology Classes of 1955 and 1962 at Eastern Illinois University for their conscientious efforts in collecting and analyzing tree count data.

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Manuscript received March 9, 1966.

NEWS AND COMMENTS

The 59th Annual Meeting is now history; but, it is not over. I heard one respected savant exclaim that he had picked up a couple of ideas that he was going to apply to his own work. Others commented on the favorable attitude of interest and enthusiasm in their sessions. Maybe these little old State Academy Meetings can be useful as a place to exchange ideas and have contact with our fellow scientists. Let the "nobs" go to the big meetings and you come to where the fun is. May I suggest that a few dozen chairs and a batch of ash-trays be stationed somewhere near the registration desk at future meetings.

On the other hand, I heard complaints about some sessions. Poor papers are really insults to the members when the author knows better. The old crack, "Oh, hell, that is good enough for the Academy" is going to cost someone a figurative bust in the snoot. I don't know how many spies were looking over possible prospects for their faculties, but I know some judging was going on.

Enough for the past meeting; let us get going on the 60th Annual Meeting. It will be held April 27, 28, and 29, 1967, at Eastern Illinois University in Charleston. If you have questions about what you should do or would want to do, seek your answers from the new President, NORMAN D. LEVINE, College of Veterinary Medicine, University of Illinois, Urbana, or the Secretary, ANTHONY E. LIBERTA, Department of Biological Science, Illinois State University, Normal. As soon as I get the word I'll publish the names of the Section Chairmen for next year's meeting. If enough people will respond (to the secretary before November, please), the Section on Aquatic Biology may be revived. Three or four members are seriously interested in such a session, but at least ten are needed.

I have instructed the printer to preserve the original pagination in preparing reprints of the "Notes." The reprints won't look as nice but citation of the pages involved will be easier. I'm sure this should not need to be mentioned, but possibly someone does not know that reference to a page should be based on the pagination of the issue and not the reprint.

Please add your "Zip number" to your own address when you write to the editor. I can see a difference already in the speed of delivery of your mail to me. My Zip number is 62901. Having the Zip number will be required on all "bulk mail" after January 1, 1967, so the secretary needs to know your Zip number, too. If you don't get your issues and announcements next year it could be because your Zip is missing. All

prospective authors please note: I need to send the Zip number to the printer so that he can mail reprints.

Here is a bit of news that I can pass along. Donald Tindall has been appointed Assistant Professor of Botany at Southern Illinois University. Mr. Tindall took his undergraduate work at Georgetown College and his graduate degrees at the University of Louisville. He has been a member of the research staffs at Woods Hole and at Indiana University where he is currently on a post-doctoral appointment. His field of interest is algae. Looks like we got one more member for that Aquatic Biology Section.

NOTES

POLYEDERS OF *PEDIASTRUM SIMPLEX*

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ABSTRACT. — Polyeders were observed after a sample of liquid and soil from a 5-year-old soil-water culture of *Pediastrum simplex* was transferred to a fresh mineral medium. These polyeders eventually produced new *Pediastrum* colonies.

Many actively swimming spherical biflagellate cells (7-8μ dia.) were observed in clear vesicles after *Pediastrum simplex* colonies from a five-year-old soil water culture had been transferred to a tube containing a modified Chu mineral medium (1963). Each cell was green except for a small clear portion from which the flagella emerged. After stopping each cell rapidly produced four tapering processes from its central mass and became a polyeder (FIG. 1). Each process terminated in a tuft of long clear bristles. These polyeders were similar to those of *P. boryanum* described by Askenasy (1888) and Palik (1933). The polyeders enlarged, ruptured the vesicle, and after a week reached a diameter of 30-40μ. When transferred to fresh mineral medium, the protoplast of the polyeders developed internal division planes and eventually completed division to form rounded parts. The rounded parts separated and became biflagellate zoospores. The zoospores (7-8μ dia.) were released through a crack in the outer wall of the polyeder in a clear vesicle. Each vesicle contained 4-32 zoospores. Within the vesicle zoospores moved rapidly and arranged themselves as a colony in a series of concentric circles one zoospore thick. After three to five minutes the zoospores became still and adhered to each other. Each of the cells of the peripheral ring then developed a single pointed spine directed radially outward. Within a day after zoospore release the young *P. simplex* colony enlarged and grew through the vesticle.

These polyeders undoubtedly are a stage in the sexual cycle of *P. simplex*, a species in which sexual reproduction has not been recorded.

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Manuscript received April 21, 1966.

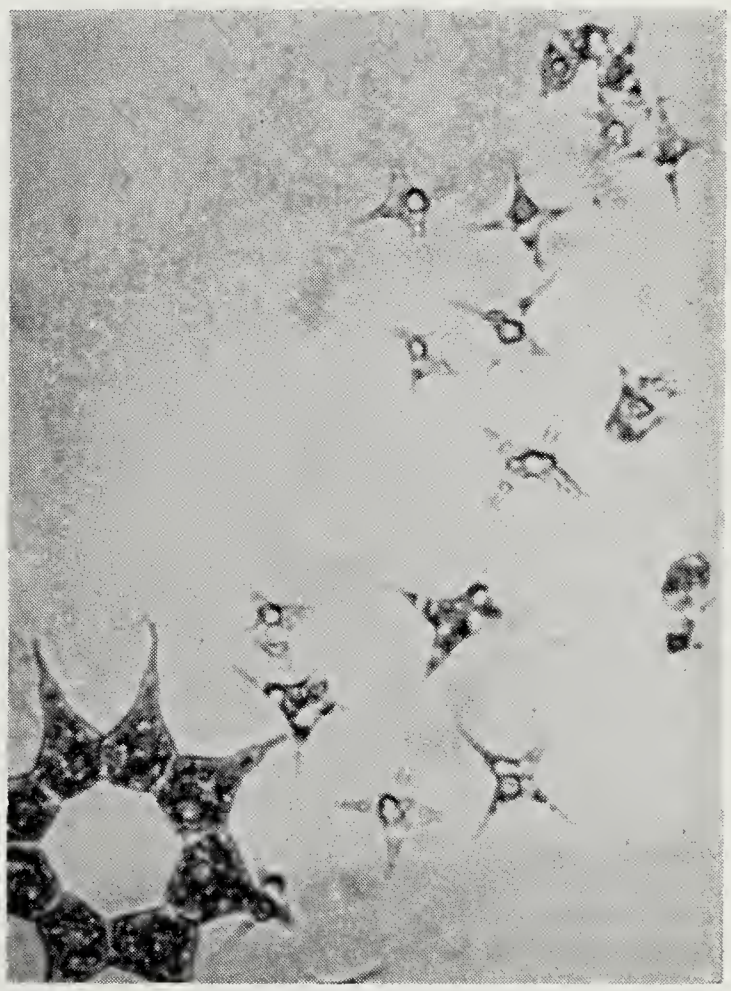

FIGURE 1. — Polyeders and an eight-celled colony (450X).

NOTES ON *EUPATORIUM* (COMPOSITAE) IN ILLINOIS

R. P. WUNDERLIN
Southern Illinois University

ABSTRACT.—Two forms of *Eupatorium* new to Illinois are reported for the first time and a note that two typical species attributed to Illinois are best treated as varieties of the species.

Recent investigations of specimens of the genus *Eupatorium* in three Illinois herbaria (Illinois Natural History Survey, Illinois State Museum, and Southern Illinois University) have led to the discovery of the following two forms not previously reported for Illinois.

Eupatorium perfoliatum L. forma purpureum Britt.

This plant differs from typical *Eupatorium perfoliatum* in having the flowers purple-colored rather than white and the phyllaries purple-tinged rather than green. The following collection is deposited in the herbarium of the Illinois State Museum: WINNEBAGO CO.: 3½ miles northwest of Rockton, September 9, 1945, *G. D. Fuller 11270.*

Eupatorium coelestinum L. forma album E. J. Alex.

This plant differs from typical *Eupatorium coelestinum* in having the flowers white colored rather than blue to purple. The following collection is deposited in the herbarium of the Illinois State Museum: CASS CO.: *R. T. Rexroat 1170.*

Further investigations in the herbaria previously mentioned and a study of the literature have led to the discovery that two species attributed to Illinois (*Eupatorium sessilifolium* L. and *Eupatorium rugosum* Houtt.) are present only as varieties (*Eupatorium sessilifolium* L. var. *brittonianum* Porter and *Eupatorium rugosum* Houtt. var. *tomentellum* (Robinson) Blake) of the typical species. The typical species and not the varieties are cited by Jones and Fuller (1955) and Winterringer and Evers (1960).

Eupatorium sessilifolium L. var. brittonianum Porter

All the herbarium materials examined fit the description of *Eupatoruim sessilifolium* L. var. *brittonianum* Porter which is characterized by having pubescent inflorescence branches. The typical glabrous species occurs in southern and eastern United States according to Fernald (1950) and is not known to be represented in the Illinois flora. Johnson and Iltis (1963) also attribute this variety to Wisconsin and not the typical species.

Eupatorium rugosum Houtt. var. tomentellum (Robinson) Blake

All the herbarium materials examined fit the description of *Eupatorium rugosum* Houtt. var. *tomentellum* (Robinson) Blake which is characterized by having tomentellous peduncles. The typical species with glabrous peduncles occurs in southern and eastern United States according to Fernald (1950) and is not known to be represented in the Illinois flora. Johnson and Iltis (1963) also attribute this variety to Wisconsin and not the typical species. On the other hand, Jones (1963) attributes the species and its variety to Illinois; Steyermark (1963) does likewise for Missouri and states that both are common.

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Manuscript received March 28, 1966.

A MICROORGANISM FOUND IN THE LATEX OF *EUPHORBIA MARGINATA* PURSH. (EUPHORBIACEAE)

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ABSTRACT. — A bacillus resembling *Bacillus megaterium* DeBary was isolated from the latex of *Euphorbia marginata* Pursh. It was found in twenty-nine of 161 plants examined for the presence of microbes.

During a search for endophytic protozoa of laticiferous plants bacteria were found in latex samples of *Euphorbia marginata* Pursh. (Euphorbiaceae). Twentynine of 161 plants examined yielded the microorganisms. The bacteria, isolated from the latex by the streak plate technique, were grown on nutrient agar, Gram-stained, stained for flagella, spores, and capsules and examined microscopically. The size of the vegetative rods and of spores was determined with an ocular micrometer using the oil-immersion objective. The colonial appearance on nutrient agar and the nature of the growth on nutrient agar, glucose nitrate agar slants, glucose agar slants, and nutrient broth was observed. The organism was also examined for the production of acid and gas from glucose, sucrose, lactose, arabinose, and xylose. Hydrolysis of casein, starch, and gelatin; reduction of nitrate to nitrite; utilization of citrate; production of acetylmethyl carbinol; production of catalase; the ability to grow on nutrient agar at pH 6; and the ability to grow anaerobically were determined according to the methods prescribed by Bradshaw (1963).

All bacterial colonies were of similar morphology. A comparison of the characteristics of isolated colonies with characteristics described in Bergey's manual of determinative bacteriology (Breed et al., 1957) indicates that only one species of bacteria is present and that the bacterium isolated from the latex is a member of the family Bacillaceae, genus *Bacillus* and resembles *B. megaterium* DeBary most closely.

Bacteria were reported previously from laticiferous plants. A bacteriological study of the latex of the rubber tree, *Hevea brasiliensis*, Muell. Arg. in Annam was carried out by Dernier and Vernet (1917). These authors isolated 27 different species of bacteria. Picado (1921), while searching for flagellates of euphorbias near Costa Rica, observed numerous bacteria in the latex of *Pedilanthus tithymaloides* Poit. He also found bacteria in the latex of *Jatropha* and *Manihot* (Euphorbiaceae), *Ficus* (Urticaceae), and *Carica* (Caricaceae). No descriptions were given. Spirochaetes have been reported as occurring in latex plants by Laveran and Franchini (1921). Franchini (1922, 1923) found bacteria (cocci and short rods) in the latex of *Lactuca sativa* L. (Compositae). He also reports some rather large spirochaetes in the latex of *Euphorbia peplus*. Corbet (1930) isolated from *Hevea* latex, a bacterium, which he described and named *Bacillus pandora*.

ACKNOWLEDGMENTS

This paper represents a portion of a thesis submitted in partial fulfillment of the requirements for the Ph.D. degree, Department of Zoology, University of Minnesota, Minneapolis, Minnesota. Sincere thanks are expressed to Dr. Franklin G. Wallace, University of Minnesota.

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Manuscript received March 25, 1966.

SPIDERS OF ILLINOIS: ADDITIONAL SPECIES

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ABSTRACT.—Thirteen species of spiders are listed as new Illinois records. Family Oecobiidae is reported for the first time in Illinois. State records now include 355 species from 26 families.

A check list of the spiders known to occur in Illinois was published by B. J. Kaston in 1955. Kaston's list included 342 species from 25 families for which positive records exist. The additional 13 species listed in the present paper expand the species total to 355 and the number of families to 26.

These new records are based on specimens collected in the Mattoon area of east-central Illinois and are now in the author's collection. The specimens were collected from stations established by the author in 1959 for the purpose of a distributional study of the spider fauna of the area. The sites at which specimens were obtained are indicated in the following list by the Township, Range, and Section code.

Family Anyphaenidae

Anyphaena fraterna (Banks). One male swept from undergrowth; T13N-R7E-S10 ½N, wooded stream bank near Cooks Mills, Coles Co., June 8, 1960.

Family Thomisidae (Crab spiders)

Synema parvula (Hentz). One female taken by sweeping; T13N-R8E-S4 ¼SE, woodslot near Humboldt, Coles Co., Oct. 12, 1959. One immature; T11N-R9E-S12 ¼SE, Fox Ridge State Park, Coles Co., Aug. 28, 1961.

Family Salticidae (Jumping spiders)

Habronattus coronatus (Hentz). Female swept from weeds; T15N-R8E-S10 ¼SW, railroad right-of-way south of Tuscola, Douglas Co., Aug. 22, 1960.

Metacyrba taeniola (Hentz). Female swept from herbs; T11N-R7E-S4 ¼NW, Lake Paradise, Coles Co., June 1, 1960. One penultimate male; T12N-R9E-S25 ¼NE, Lake Charleston, Coles Co., Oct. 15, 1960.

Myrmarachne hentzi Banks. One female; T11N-R9E-S21 ¼SE, Lincoln Log Cabin State Park, Coles Co., June 3, 1961.

Peckhamia americana (Peckham). Female swept from vegetation near bridge; T13N-R6E-S17 ¼SE, near Allenville, Moultrie Co., July 10, 1961. Female swept from tall weeds; T11N-R4E-S2 ¼NE, Lithia Springs Park, Shelby Co., June 6, 1962.

Family Oecobiidae

Oecobius texanus Bryant. Female swept from underbrush; T11N-R10E-S19 ¼NW, woodslot 6 miles south of Charleston, Coles Co., June 9, 1960. This is the first record of the occurrence of this family in the state.

Family Araneidae (Typical orb-weavers)

Neoscona minima F. O. P. Cambridge. Males and females common. T15N-R8E-S10 ¼SW, railroad right-of-way south of Tuscola, Douglas Co., June 26, 1960. T15N-R7E-S12 ¼SW, pasture 6 miles southwest of Tuscola, Douglas Co., Sept. 17, 1960; June 23, 1962. T14N-R5E-S15 ¼SW, farm 4 miles north of Sullivan, Moultrie Co., July 1, 1960. T12N-R6E-S32 ¼NW, farm near Windsor, Shelby Co., June 21, 1960. T9N-R7E-S18 ¼NW, farm near Sigel, Cumberland Co., Aug. 24, 1960; June 14, 1962.

Family Lycosidae (Wolf spiders)

Pirata maculatus Emerton. Mature female, two immatures taken on bare soil near water; T12N-R9E-S25 ¼NE, Lake Charleston, Coles Co., June 6, 1960.

Family Oxyopidae (Lynx spiders)

Oxyopes scalaris Hentz. One female taken by sweeping; T11N-R4E-S2 ¼NE, Lithia Springs Park, Shelby Co., June 6, 1962.

Family Clubionidae
(Sack spiders)

Clubiona pygmaea Banks. One female; T12N-R9E-S25 ¼NE, Lake Charleston, Coles Co., June 30, 1961.

Castianeira gertschi Kaston. Female found on door screen of house; T12N-R7E-S14 ¼NW, Mattoon, Coles Co., May 25, 1960.

Family Uloboridae
(Hackled-band orb-weavers)

Uloborus octonarius Muma. Very common in horizontal or inclined orb webs on rafters in barns and sheds. T11N-R7E-S12 ¼SW, in barn and sheds on farm 4 miles south of Mattoon, Coles Co., June 1, 1960; Aug. 24, 1960; June 21, 1961. T10N-R7E-S1 ¼SE, in barn on farm 4 miles east of Neoga, Cumberland Co., Oct. 31, 1959; June 2, 1960; June 23, 1961.

Acknowledgments

The author wishes to express his gratitude to Dr. Willis J. Gertsch of the American Museum of Natural History for his help in identifying the specimens on which this list is based. Thanks are also due Dr. Arthur C. Cole of the University of Tennessee for his helpful suggestions during the preparation of this paper.

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NOTES ON A COLLECTION OF AMPHIBIANS AND REPTILES FROM MONROE COUNTY, ILLINOIS

RONALD A. BRANDON and NATHAN R. AUSTIN
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ABSTRACT. — *Scaphiopus holbrooki*, the eastern spadefoot, is reported from Monroe County, Illinois, for the first time. Additional specimens of *Elaphe guttata emoryi*, the Great Plains rat snake, and *Tantilla gracilis hallowelli*, the northern flatheaded snake, are noted.

During the months of April and May, 1965, the junior author collected amphibians and reptiles along the blacktop road connecting the town of Prairie du Rocher in Randolph County, and Illinois Route 3, one mile south of Columbia, in Monroe County, Illinois. One species is previously unreported from Monroe County, and specimens of two others are of interest due to the paucity of material from Illinois (cf. Smith, 1961).

Scaphiopus holbrooki

Smith (op. cit.) reported 20 specimens of this species, ranging from 26 to 59 mm snout to vent, from Alexander, Jackson, Johnson, and Union counties. Our one male specimen (SIU H-2095), 73 mm snout to vent, was found three miles north of Fults during the evening of 24 April 1965. In addition to extending the known range in Illinois northwestward by two counties and about 60 miles, the specimen increases the known body length of Illinois specimens by 14 mm.

Elaphe guttata emoryi

According to Smith (op. cit.) six specimens are known from Illinois, and four of these are from Monroe County. Our four additional specimens were collected along the Fults to Valmeyer Road, and in addition to increasing the number of extant Illinois specimens, they enlarge the known range of variation here in some scale characters. On 14 May 1965, SIU R-1234 was collected 2½ miles north of Prairie du Rocher; SIU R-1238, 1 mile south of Valmeyer; and SIU R-1202, 9 miles north of Valmeyer. On 22 May a fourth specimen, SIU R-1211, represented by only the head and tail, was found 8 miles north of Fults. All were found dead on the road. The specimens, two males, one female, and one undetermined juvenile, vary as follows, respectively: total length 1070, 1050, unknown, 450 mm; tail 17.7, 17.5, unknown, 17.7% of total length; ventrals number 208, 209, unknown, 224; caudals 70, 63, 60, 81; dorsal blotches 44, 48, unknown, 39; blotches on tail, 12, 12, 10, 11; infralabials 10-10, 11-11, 12-11, unknown; supralabials 8-8, 8-8, 8-8, unknown; body scale rows 25-25-19, 24-27-18, unknown, unknown.

Tantilla gracilis hallowelli

Of the 13 known specimens collected in Illinois, three are females from Monroe County (Smith, op. cit.). One additional specimen (SIU R-1229), a female, was collected 10 April 1965, 2 miles south of Fults. Its total length is 200 mm, the tail makes up 22.5% of total length, and it has 125 ventrals, 46 caudals, 15 scale rows, 6-6 supralabials, 6-6 infralabials.

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SMITH, P. W. 1961. The amphibians and reptiles of Illinois. Illinois Natural History Survey Bulletin 28(Art. 1):1-298.

Manuscript received April 4, 1966.

KILL OF MAMMALS AND BIRDS AND ENTRAPMENT OF TURTLES ON RAILROAD TRACKS

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ABSTRACT. — The kill of wildlife on railroads consisted of various species of mammals and birds as well as the entrapment of turtles. Opossums (*Didelphis marsupialis*), domestic dogs (*Canis familiaris*) and box turtles (*Terrapene* sp.) were the most common victims.

Information on kills of wildlife on railroad tracks if known is unpublished. In late January and February, 1962, a limited investigation of such types of kill was made by walking approximately 18 miles of railroad tracks in Jackson County, Illinois. Three separate railroad tracks were walked as follows: The Gulf, Mobile and Ohio Railroad south of Murphysboro (8.8 miles from the Big Muddy south to Pomona); the Illinois Central Railroad (6.7 miles from 1 mile south of Carbondale to Makanda); and the Missouri Pacific Railroad (3 miles northwestward from DeSoto).

There was found to be tremendous variation in kill on these three tracks. The Gulf, Mobile and Ohio Railroad tracks had 75% of the total kill with an average traffic of about 45 freight trains per week. These tracks passed through areas of wooded flood plain (ca. 5 miles) and rolling farmland with wood lots (ca. 4 miles). The Illinois Central tracks had 23% of the total kill with an average traffic of 175 freight and passenger trains per week. The area was gently rolling, partly wooded agricultural land (ca. 2 miles) and along a partially wooded creek (ca. 4.5 miles). The Missouri Pacific tracks were travelled predominantly by local slow moving trains hauling coal. Only 2% of the total kill was taken in this uniform, gently rolling agricultural area.

Found in this short survey were nine species of mammals: 13 opossums (*Didelphis marsupialis*), 11 dogs (*Canis familiaris*), 4 cats (*Felis catus*), 4 woodchucks (*Marmota monax*), 3 cottontails (*Sylvilagus floridanus*), 2 skunks (*Mephitis mephitis*), 1 raccoon (*Procyon lotor*), 1 deer (*Odocoileus virginianus*), 1 grey fox (*Urocyon cinereoargenteus*); five species of birds, one of each of the following: bobwhite quail (*Colinus virginianus*), mourning dove (*Zenaidura macroura*), domestic chicken (*Gallus gallus*), screech owl (*Otus asio*), and barred owl (*Strix varia*); and three species of turtles (as follows): 36 box turtles (*Terrapene* sp.), two musk turtles (*Sternotherus ordoratus*), and two sliders (*Pseudemys* sp.).

Of special interest is the number of turtles found. Apparently turtles find an entrance between the rails where the roadbed of the track is eroded between the ties and under the rail. Once between the tracks, finding another such opening becomes a matter of chance resulting in the turtles becoming trapped between the rails and eventually dying. Where wooded hillsides bordered a stream of flood plain, an average of one box turtle was found every 0.25 mile.

Manuscript received April 25, 1966.

HERPETOLOGICAL RECORDS FROM NORTHCENTRAL ILLINOIS

J. ALAN HOLMAN

Illinois State University, Normal

ABSTRACT. — Twenty-one species (one salamander, five anurans, three turtles, and 12 snakes) were recorded in four years of collecting near Normal in north-central Illinois. This impoverished herpetofauna no doubt reflects the fact that agricultural crops have largely replaced the original vegetation of the area.

Much of Illinois has been intensively studied herpetologically (Smith, 1961), but little has been recorded recently concerning the highly agricultural north-central part of the state. For this reason I have made concentrated efforts to collect amphibians and reptiles from localities near Normal, Illinois during a four year period from September, 1961 through September, 1965. Sixty-two collecting trips (each of about two to three hours duration) were taken as follows: 1961(3), 1962(20), 1963(4), 1964(13), and 1965(22). Most trips were taken in the months of April, May, and June. Several casual trips were not recorded. Herpetological records for the area date back to those of Garman (1892), thus it is possible to note apparent changes that have taken place in the herpetofauna during the past 73 years. The most recently published records of the herpetofauna of the area are those of Smith (op. cit.) in his comprehensive study of the amphibians and reptiles of Illinois.

The localities studied lie in the Bloomington Ridged Plain physiographic division of Illinois (Leighton et. al., 1948) and in the Grand Prairie herpetofaunal division of Smith (op. cit.). Almost all of the original prairie vegetation is now under cultivation. Thus, most collecting sites are road shoulders, railroad right-of-ways, vacant lots, artificial ponds and lakes, and a few oak-woodlands found mainly along the Mackinaw River in the northern part of the area, and along Sugar Creek and Kickapoo Creek in the southwestern part.

A list of localities follows. Localities 1-16 are in McLean County, Locality 17 is in Logan County, Locality 18 is in DeWitt County: (1) 4 miles west of Bloomington, (2) Clarksville, (3) Downs, (4) Funk's Grove, (5) Heyworth, (6) 3 miles east of Heyworth, (7) Hudson, (8) Lake Bloomington, (9) Lexington, (10) McLean County Conservation Area, (11) Normal, (12) 2 miles northeast of Normal, (13) 2.5 miles southeast of Stanford, (14) 5 miles southeast of Stanford, (15) near Middle Fork of Sugar Creek, 3 miles northeast of Stanford, (16) Towanda, (17) near Sugar Creek, 5.6 miles west of McLean, (18) Wapella.

Herpetological records from this study and from previous studies in the area are summarized in TABLE 1. The fact that nine species previously reported were not taken during the present study leads me to believe that a rather large portion of the original herpetofauna is rare or has become extinct. This no doubt reflects the fact that the original vegetation of the area has largely been replaced by agricultural crops.

The three available *Lampropeltis triangulum* (Lacèpédo) specimens from McLean County appear to be intergrades between *L. t. triangulum* (Lacépède) and *L. t. syspila* (Cope). Smith (op. cit. p. 176 and p. 221 fig. 208) discusses characters that differentiate the two subspecies, and he indicates that they intergrade in approximately the southern one-half of the area studied. The specimen from Locality 10 may be closer to *syspila* than to *triangulum* in that it has 34 brown dorsal blotches that extend to scale rows 1 and 2. A juvenile specimen from Locality 2 is possibly closer to *triangulum* than to *syspila* in that it has 51 reddish-brown dorsal blotches that extend down to scale rows 3 and 4. A newly hatched specimen from Locality 1 has 44 reddish dorsal blotches that extend down to scale row 3.

TABLE 1.—Records of Amphibians and Reptiles from Northcentral Illinois. C, common, O, occasional, R, rare. Last records are from Garman (1892), Dunn (1918), and Smith (1961).

Species	Last Record	Localities of the Present Study																
		4 mi. W. Bloomington	Clarksville	Downs	Funk's Grove	Heyworth	3 mi. E. Heyworth	Hudson	Lake Bloomington	Lexington	McLean Cons. Area	Normal	2 mi. NE. Normal	2.5 mi. SE. Stanford	5 mi. SE. Stanford	Mid. Sugar	Towanda	5.6 mi. W. McLean	Wapella
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Ambystoma texanum (Matthes)	1961																		
Ambystoma t. tigrinum (Green)	1961						R												
Notopthalmus viridescens (Rafinesque)	1918																		
Bufo a. americanus Holbrook	1961		C					C	C	C	C	C							
Acris crepitans blanchardi Harper	1961					C			C		C	C							
Hyla v. versicolor LeConte	1961																		
Pseudacris t. triseriata (Wied)	1961		C						C			C				C			
Rana catesbeiana Shaw	1961				C			C	C			C							
Rana pipiens Schreber	1961								C			C							
Chelydra s. serpentina (Linnaeus)	1961											O							
Emydoidea blandigi (Holbrook)	1892																		
Chrysemys picta (Schneider)	1961								C			O							
Trionyx s. spinifer Le Sueur	1961								O									R	
Ophisaurus a. attenuatus (Cope)	1892																		
Opheodrys vernalis blanchardi Grobman	1961													R					
Coluber constrictor flaviventris Say	1961																	R	
Elaphe o. obsoleta (Say)	1961																		R
Elaphe v. vulpina (Baird and Girard)	1961		C		C				C	C	C	C					C		
Pituophis melanoleucus sayi (Schlegel)	1961										R								
Lampropeltis c. calligaster (Harlan)	1961				C										C			C	
Lampropeltis triangulum (Lacépède)	1892	R	R								R								
Thamnophis proximus (Say)	1961																		
Thamnophis r. radix (Baird and Girard)	1961							C	C		C	C	C	C				C	
Thamnophis s. sirtalis (Linnaeus)	1961		C	C	C				C			C						C	
Storeria dekayi wrightorum Trapido	1961		C		C				C			C							
Storeria o. occipitomaculata (Storer)	1892																		
Clonophis kirtlandi (Kennicott)	1961								R										
Natrix grahami (Baird and Girard)	1961																		
Natrix s. sipedon (Linnaeus)	1961								C		C							C	
Sistrurus c. catenatus (Rafinesque)	1892																		

Smith (op. cit. p. 233-234) lists characters of the two Illinois subspecies of *Thamnophis sirtalis* (Linnaeus) and he indicates that *T. s. sirtalis* (Linnaeus) intergrades with *T. s. semifasciata* (Cope) in the northern part of McLean County, but that there is no intergradation just south of Bloomington and Normal. In the 14 specimens at hand from Locality 17 I find that the black crossbars that interrupt the lateral stripes anteriorly are prominent in 5, weak in 6, and absent in 3. Thus, it seems that the *semifasciata* influence may extend farther south than indicated by Smith. A red pigment in the groundcolor was present in all three specimens collected from Locality 4 and occurs now and then in other populations in the area (see Smith, op. cit. p. 231-232 for a discussion of this red pigmentation).

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Smith, P. W. 1961. The amphibians and reptiles of Illinois. Ill. Nat. Hist. Surv. Bull. 28(1):1-298.

Manuscript received October 26, 1965.

A GUIDE FOR TYPING MANUSCRIPTS FOR ILLINOIS ACADEMY OF SCIENCE PUBLICATIONS

EDWIN C. GALBREATH

Southern Illinois University, Carbondale

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Vol. 59, no. 4

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14

TRANSACTIONS

OF THE

ILLINOIS STATE ACADEMY OF SCIENCE

VOLUME 59 - 1966 No. 4

ILLINOIS STATE ACADEMY OF SCIENCE
AFFILIATED WITH THE
ILLINOIS STATE MUSEUM DIVISION
SPRINGFIELD, ILLINOIS

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

OTTO KERNER, *Governor*

DECEMBER 1, 1966

CONTENTS

Charles Frederick Hottes (1870-1966).
By G. Neville Jones 303
Hatching and the Hatching Muscle in Some North American Ducks.
By Harvey I. Fisher 305
Efforts to Prevent the Extinction of the Prairie Chicken in Illinois.
By Glen C. Sanderson and William R. Edwards 326
Some Aspects of Golden Mouse Ecology in Southern Illinois.
By Lawrence J. Blus 334
Mitochondrial Respiration in Mammalian Liver During Cold Exposure and Hibernation.
By John L. Frehn 342
An Occurrence of *Hexagonaria* in the Grand Tower Formation of Southern Illinois and Southeastern Missouri.
By George H. Fraunfelter 347
The Morphology, Migration and Pressure Development of Oriented Plasmodia of the Slime Mold.
By Donald M. Miller and John D. Anderson 352
Characteristics of a Yellow Bacterium Isolated from the Tissue of Jonathan Apple Trees.
By J. H. Smith and Dwight Powell 358
The Effect of Light on the Amino Acid Metabolism of *Diplodia zeae.*
By Diane Tegtmeier and A. J. Pappelis 364
Botanical Field Studies in the Southern Tip of Illinois.
By John Schwegman and Robert H. Mohlenbrock 369
Various Methods of Solving a First Order Perturbation Equation.
By Boris Musulin 373
News and Comments 382
Scale of Illustrations of Illinois Haloragaceae.
By Robert H. Mohlenbrock and Edwin C. Galbreath 385
A New Form of *Houstonia pusilla* from Illinois.
By R. P. Wunderlin and W. E. Hopkins 386
Some *Liatris* New to Illinois.
By R. P. Wunderlin 387
Production of Indoleacetic Acid by *Cephaliophora tropica.*
By J. N. BeMiller and A. J. Pappelis 388
Effects of Flooding on the Mouse, *Peromyscus leucopus.*
By Ronald W. Turner 390
Notes on Colorado Resupinate Basidiomycetes.
By Anthony E. Liberta 392
Fluorescent Maillard Reaction Artifacts in Plant Extracts.
By J. N. BeMiller 394
Lophotrichus brevirostatus, A Fungal Species New to Illinois.
By Felix A. Tornabene and Joseph S. Davis 396
A Collection of Madtom Catfish, *Noturus funebris,* from Western Florida.
By Jamie E. Thomerson 397
Some Physiological Studies on Two Strains of the Green Alga *Coelastrum microporum* Naeg.
By J. Gates, J. Anderson, D. L. Lynch and M. G. Fenwick 399
Growth of *Diplodia zeae* in Shaker Culture.
By R. A. Katsanos and A. J. Pappelis 401
Survival of Transplanted Yellow-Poplar Seedlings and Root Food Reserves.
By A. R. Gilmore 405
Academy Business 407

CHARLES FREDERICK HOTTES (1870-1966)

G. NEVILLE JONES
University of Illinois, Urbana

This is a memorial to Charles Frederick Hottes, Professor of Botany, Emeritus, and former Head of the Department at the University of Illinois, who died at his home, 406 West Iowa Street, Urbana, at 8:20 P.M., on Friday, April 15, 1966. He was 95 years old.

Professor Hottes was born July 8, 1870, in Mascoutah, St. Clair County, Illinois, three years after the founding of the University of Illinois at Urbana. He was thus one of the oldest living faculty members of the early years. For nearly eighty years he had been affiliated continuously with the University from the time of his student days beginning in 1887, until his retirement in 1938, and to 1966 as Professor Emeritus.

He was a member of the class of 1891, University of Illinois, and was a Fellow in Biology 1894-95. He received his M.S. degree in 1895, and was an Assistant from 1895 to 1898. He went to Germany for graduate work in plant physiology, as there were no graduate courses in the subject offered in this country at that time. He received the degree of Doctor of Philosophy in Botany in 1901 at the University of Bonn. He studied there under the direction of Eduard Strasburger, one of the pioneers in the study of cell formation and cell division, who thus initiated cytology as a special branch of science. Dr. Hottes returned to the University of Illinois as an Instructor, 1901-03. He was an Assistant Professor, 1903-13, and Professor of Plant Physiology, 1913-38. He served under Thomas Jonathan Burrill, who was succeeded after 1913 by William Trelease, who came here from the Missouri Botanical Garden at St. Louis. Both of these men were distinguished scholars and builders of science and Professor Hottes thrived with them. He was head of the Department of Botany from 1928 until 1938.

For half a century Professor Hottes taught botany to thousands of students. His practical contribution to the development of botanical science was made chiefly through his teaching rather than by research or writing. Although his principal interest was plant physiology, he taught general botany, plant cytology, and plant taxonomy with nearly equal facility. He filled the classrooms with enthusiastic and capable students. He was a lucid exponent of whatever subject he was lecturing about. His tone was loud and incisive, and his approach to his subject was straightforward, simple, and direct. He realized the need for studies of the physiological responses of economic crops, and many of his

graduate students went on to productive careers in applied fields. His design of growth chambers for the study of plants under controlled environmental conditions was appreciated and widely adopted.

From 1923 to 1938 Professor Hottes was a consulting plant physiologist to the Department of Agronomy, where he held a joint academic appointment. His membership in professional societies included the AAAS, Botanical Society of America, the American Society of Plant Physiologists, and the Illinois State Academy of Science. He was a 50-year member of the Urbana Lodge 157, AF and AM; Urbana Chapter 80, Royal Arch Masons; Urbana Council 19, Royal and Select Masters and Urbana Commandery 16, Knights Templar, and a life member of the Valley of Danville, Scottish Rite Consistory. He was a 40-year member of Kiwanis Club, a life member of Acacia fraternity, and member of Sigma Xi and Alpha Zeta honorary fraternities. He was an enthusiastic traveler and photographer. He traveled in Alaska, Canada, Mexico, and Central America, and made records on film. At the age of 72 he took a trip down the San Juan and Colorado rivers in an open boat.

Although Professor Hottes travelled a good deal he was not primarily a collector of plants. His chief contribution to systematic botany was made through his classroom teaching, and his organization of the herbarium. While T. J. Burrill (1839-1916) and later, W. Trelease (1857-1945) had built up the botanical collections to about 100,000 specimens, it was Hottes who designed the first section of the herbarium at the University of Illinois and installed in 1922 ninety or more small metal cases in the relatively fireproof east wing of the Natural History Building. Since that time the herbarium has grown to include nearly half a million accessions.

Professor Hottes was an indefatigable gardener, and his home grounds reflected his interest in plants of all kinds. The unusual displays attracted and fixed the attention of passers-by over the years. He was a true naturalist. We have all benefited by the services he rendered to his science and to his University.

Publications by C. F. Hottes

1926. Coöperative research in plant physiology and agronomy. Journ. Am. Soc. Agron. 18: 60-68, f. 1-4.

1929. Studies in experimental cytology. Plant Physiol. 4: 1-30, pl. 1 + f. 1-4.

1932. The contribution of botany of Julius von Sachs. Ann. Missouri Bot. Gard. 19: 15-30, pl. 2.

1940. Personal recollections of Thomas J. Burrill and his work. Illinois Alumni News 18(5): 6-7, portr.

(with H. K. Wilson)

1930. Resistance of wheat to high temperatures under different methods of heating. Journ. Am. Soc. Agron. 22: 108-112.

HATCHING AND THE HATCHING MUSCLE IN SOME NORTH AMERICAN DUCKS

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ABSTRACT. — The pre- and early post-hatching development of the hatching muscle, M. complexus, is described for eight species of ducks. Its pattern of change in conformation and mass is similar to that known for other birds. The time of occurrence of certain events in development appears to be correlated with length of incubation period rather than with biomass. Movement of lymph into and out of the hatching muscle constitutes the major factor in the changes in bulk of the muscle. Actual weight of the muscle at the time of pipping is roughly correlated with thickness of egg shell in ducks, as it is in grebes, but these correlations exist only within closely related phylogenetic lines in birds. It is suggested that genetic background and factors such as humidity and composition of the shell are also significant in the history of the hatching mechanism.

The time required for a single egg to hatch (from pip to emergence) is highly variable with species, season, chronological position in the clutch and, in American Coots at least, with the number of eggs in the clutch. Hatching time of a clutch (time from pip of first egg to emergence of last duckling) appears to be specifically and seasonally variable, as is emergence time (period of emergence from first to last duckling), but the latter time is much shorter in precocial species.

The hatching mechanism in the Ruddy Duck (Oxyurinae) shows major differences from that in the Anatinae and the Aythyinae in which it is similar.

The hatching muscle in birds was first considered to be the caput part of the M. cucullaris of Fürbringer (1888:1056). Since it is a true skeletal muscle in its own right and has been called M. complexus, George and Berger (1966:272) favor retention of the latter name. I agree.

Early modern studies of M. complexus aroused a minor controversy about its function. Rosenstadt (1912) regarded it as a relict with no functional significance, but Keibel (1912) believed that it furnished the power to thrust the egg-tooth of the embryo against the inner surface of the egg shell and thus effect the first break in the shell. Pohlman (1919:101) stated that the muscle was ". . . relaxed at the time of picking through the shell," and consequently the muscle could not be a functional part of the hatching mechanism.

In a series of studies in 1958, 1961, and 1962, H. I. Fisher suggested that: 1) M. complexus was indeed the power for the egg-tooth; and 2) it was likely that lymph, infiltrating the muscle just before hatching, carried nutrients for the temporarily high energy requirements of the muscle.

Driver (1960) working with the Common Eider (*Somateria mollissima*), the Oldsquaw (*Clangula hyemalis*), and the Redbreasted Merganser (*Mergus serrator*) reported that the "upward nod" was the most obvious movement of the head

in the immediate pre-hatch stage and that this "nod" did bring the egg-tooth against the shell in typical pipping motions.

In 1963 George and Iype found lipase activity and a high glycogen content in M. complexus of the chick at the time of hatching, as well as in the pectoralis muscles. Their conclusion was that the hatching muscle powered the pipping process and aided in the final emergence from the shell but that the pectoralis muscles probably were the primary factor in the actual emergence of the chick.

Embryos of all avian species must in some way escape from the heavy, calcified shell, but all the experimental studies of hatching have thus far concerned themselves only with the domestic chicken. The presence of a hatching muscle with a developmental history that would make possible a contribution to hatching has been demonstrated only in the: domestic chicken (H. I. Fisher, 1958); American Coot (*Fulica americana*) (J. R. Fisher, 1962); Franklin's Gull (*Larus pipixcan*), Common Tern (*Sterna hirundo*), and Black Tern (*Chlidonias niger*) (H. I. Fisher, 1962); and in five species of North American grebes (Family Podicipedidae) (H. I. Fisher, 1961).

When the mechanical and physiological aspects of hatching become known in more species of birds, we shall undoubtedly discover considerable variation. As yet we are in no position to generalize — as is indicated by the observations of Wetherbee and Bartlett (1962) who found in the American Woodcock (*Philomena minor*) and the Willet (*Catoptrophorus semipalmatus*) that the neural processes of the cervical and thoracic vertebrae formed a ridge that ripped the shell longitudinally.

Consequently, it remains desirable to study additional groups of birds to determine the method of emergence, the occurrence of the muscle and the gross features of its development, with particular emphases on the time of maximum size and on the amount and period of infiltration of lymph.

The purpose of this paper is to report investigations of the embryological features of the hatching muscle in some North American ducks and, as adjuncts of the study, to present information on the thickness of the egg shell at hatching, hatching times for clutches and for single eggs, body weights at hatching, fertility and hatchability.

Methods and Materials

Duck eggs collected for this study included: Mallard 44, Gadwall 39, Pintail 43, Blue-winged Teal 123, Shoveler 57, Redhead 182, Canvasback 3, and Ruddy Duck 69. The actual number of each species used for each aspect of the investigation is indicated in the figures and tables. Canvasbacks were rare and no attempt was made to secure an adequate series. Although Redheads were also scarce and extensive collecting thus undesirable, it was possible to obtain a significant number of eggs from "dump nests," eggs deposited by several females and which represented reproductive "losses" in any event since they are usually not incubated. The collections were made in the marshes at the south end of Lake Manitoba between the villages of Delta and St. Ambroise, Manitoba, Canada, and in the "Pothole Country" near Minnedosa, Manitoba.

Methods and conditions employed for incubation of eggs and study of the size of the hatching muscle were the same as those employed by H. I. Fisher (1961). At the time of this study in 1960 the possible effects on hatching time of physical contact between the

eggs of a clutch (Vince, 1964) or of vocalizations (Vince, 1966) had not been postulated. The duck eggs of a clutch were arranged in linear fashion in a single trough in the incubator and, although there was no contact with eggs of other clutches of the same or other species, eggs of several clutches were at times within the audio range of sounds made by various ducklings.

Since study of synchronization of hatching within a clutch was not an objective of this investigation and since the only possible effects yet attributed to contact and sound are reported to occur in the 24 hours prior to hatching, it seems likely that the random contacts and sounds produced, if anything, only an increased variability in the ratios of hatching muscle to body weights.

The thickness of the shell was measured in ten thousandths of an inch with machinist's dial calipers. Each shell was measured immediately after hatching. The thickness was determined by averaging the measurements of three randomly-selected areas at the "pip end" of the egg; variation between these three thicknesses was less than 10%, but it is recognized that the shells may have thinned during incubation.

Computation of the "lymph area" was made by multiplying greatest length by greatest width. Since the width was variable, and the glands often roughly triangular in shape, "area" simply represented a convenient and approximate composite index to size rather than an accurate measurement of space covered.

Weights of ducklings "at hatching" were made before 10 hours of age. Since intruded yolk was included at hatching and not with any embryos before hatching, the apparent increase between pipping and hatching weights was not real.

Information on the hatching process, particularly the time span between the first pipping of an egg and the emergence of the duckling and the time between emergence of the first and last ducklings in a brood, was obtained by continuous observation of the clutch after the first egg pipped. Time was not available to watch all clutches used in this study. Our conclusions were based on watching the process in: 4 clutches of Ruddy Duck eggs, 4 of Redheads, 7 of Blue-winged Teals, 1 of Shovelers, and 2 of Pintails. Observations were also made on 15 clutches of Franklin's Gulls, *Larus pipixcan* (H.I. Fisher, 1962) and of 5 clutches of the American Coot, *Fulica americana* (J.R. Fisher, 1962).

Incubation of clutches of the same species, laid at different times, made feasible a few observations on possible seasonal differences in hatchability and hatching time.

Data on fertility and hatchability were kept on all clutches. All eggs were candled before being put in the incubators, but all were incubated for a week before any were discarded as infertile.

Observations on the Hatching Muscle

General features. — M. complexus in all species investigated was a three-segment, occasionally four-, paired muscle on the dorsal aspect of the neck (Figs. 1,2). Most anteriorly it spread laterally and ventrally to cover a bit of the side of the neck in the region of vertebrae 1 and 2. It was superficial to the biventer cervicis and spinalis muscles. Without exception, each muscle of the pair was widest anteriorly where it inserted fleshily on the posterior, parietal crest of the skull between the origins of the two depressor mandibularis muscles and between the most dorsal tips of the hyoid apparatus.

The origin of the muscle was, for the most part, tendinous and from the dorsal surfaces of the transverse processes of cervical vertebrae 3 and 4, but there was some fibrous attachment to the lateral surfaces of the neural spines of these vertebrae.

Segmentation. — Segmentation of the muscle was first indicated by a transverse line between segments 1 and 2; in all species this occurred when body weight reached 5 to 9 grams. Within a species the time of first appearance of segmentation was even more uniform— for example, between 6 and 8 grams in the Redhead and 5 to 7 in the Blue-winged Teal and Gadwall.

Segment 3 showed when body weight became 1 or 2 grams greater (7 to 11 grams) except in the Mallard in which it appeared with a 13-gram body weight.

It was only at the prepip stage that the fourth segment (not found in the Ruddy Duck) became visible in the Mallard, Shoveler, and Gadwall. In the Blue-winged Teal and Redhead, segment 4 showed only after hatching, but it was present at the prepip and just-hatched stages in the Pintail.

Segmentation was faint or completely masked, temporarily, at the time of pip-

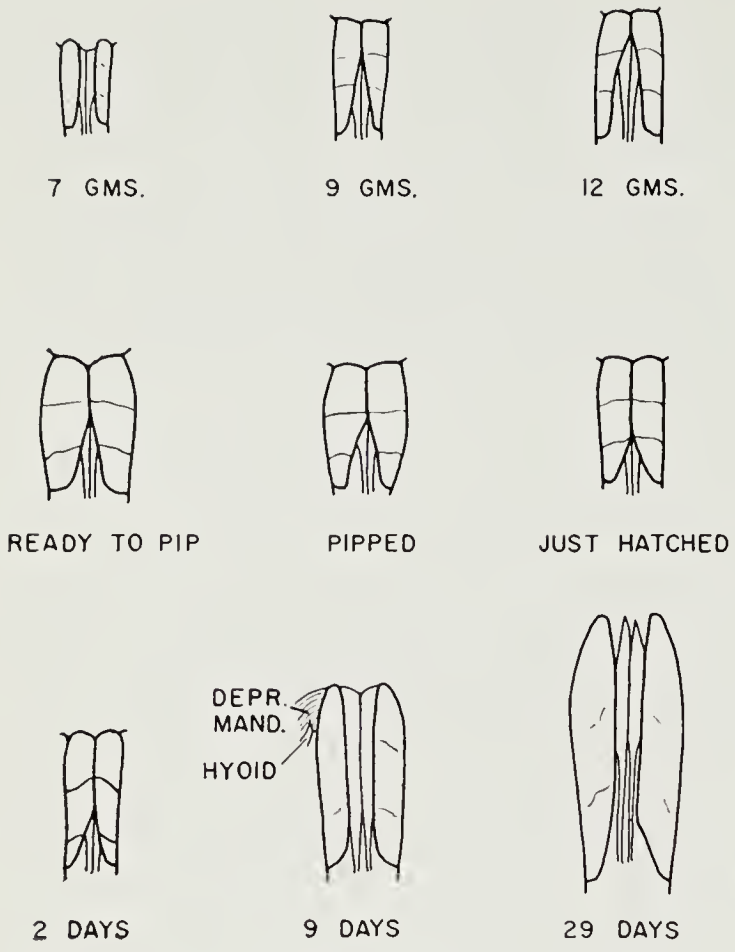

FIGURE 1. Sketches of dorsal views of hatching muscles in Blue-winged Teals of different ages. X⅔. (Weights indicated are body weights.)

ping, reappeared during hatching, and became progressively obscure (Fig. 1, Blue-winged Teal) or absent within 30 days after hatching (Fig. 2, Mallard). In the Shoveler, segments were not visible after 6 days of age, and many of the Blue-winged Teals showed no segmentation after 9 days.

Relative sizes of the segments for the Blue-winged Teal are illustrated in Figure 1; they are typical of all the ducks studied. Segment 4, when present, was a much-attenuated structure no more than half the size of segment 3 (Fig. 2, Redhead).

Although there was little or no change in this relative size of the segments during development, the segments increased in absolute size (Fig. 1). The expansion was in all dimensions, but primarily in width and in thickness.

The most easily observed indication of this rapid growth was the degree of medial extension and the extent to which the segments hid from view the underlying Mm. biventer cervices.

In the Blue-winged Teal, a typical species in these developments, embryos of 3 grams total weight possessed hatching muscles consisting of two thin bands lying side by side and touching each other throughout their length. Between the 4- and 6-gram stages the muscle bands began to separate from one another, and they were usually completely apart at 7 grams of body weight. Within the span of a day or so, and an increase of one or two grams in body weight, the anterior ends of the pair of muscles were again in contact along their medial edges (Fig. 1). Contact between the muscles continued progressively caudad until the pipping and hatching stages when, in more than half the embryos, the inner edges touched throughout their length. In the fourth or fifth day of age the muscles

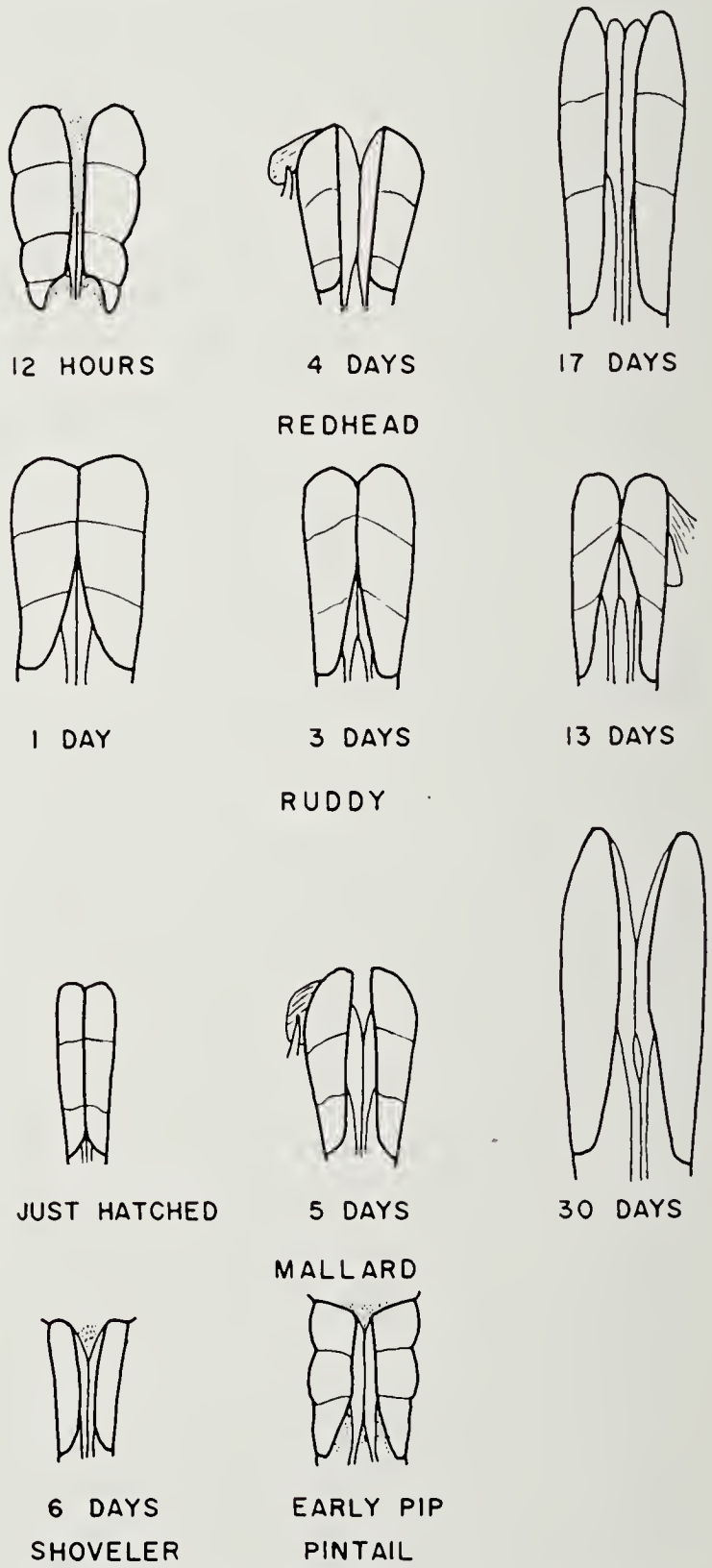

FIGURE 2. Sketches of dorsal views of hatching muscles in five species of ducks. X¾

of the two sides separated permanently; this dissociation began at the posterior end and proceeded anteriorly to the junction of segments 1 and 2 while a slower disengagement was initiated at the anterior end. The process is shown for the Ruddy Duck in Figure 2.

The Shoveler's development in this regard was the same as the Blue-winged Teal's except that medial contact between the two sides was initially lost at 9 grams of body weight, and final separation took place 2 days after hatching. The only variation between the Teal and the Pintail was that the body weight in the latter was approximately 12 grams when the muscles first separated. Embryos of the Gadwall exhibited great individual variation in the degree of contact between the two sides, but in all instances the contact was less than in the other species.

In the Redhead the initial, complete separation was found in only a few specimens; most maintained contact in the middle third of the muscles' length. Another major variation from the pattern of the Blue-winged Teal was that the muscles of the two sides became distinct and completely separate entities within hours after hatching (Fig. 2), and occasionally even before hatching.

Neither the Mallard nor the Ruddy Duck exhibited the first separation of the muscles and a greater degree of contact was maintained for a longer, post-hatching period. In the Ruddy, even at 13 days, the muscles still touched each other.

Infiltration of lymph. — Indications of the presence of lymph were several: A change in the color of the muscle from dark pink to yellow-pink to straw-yellow; an increase in the number of "lymph areas"; greater size of the areas; and finally, to be discussed later, enlargement of the muscle masses as measured by weight and turgidity.

The presumed, immediate source of this lymph was a gland, roughly triangular in shape, that laid along the lateral edge of either muscle and a lymph spot that appeared between the separated anterior ends of the Mm. biventer cervices and deep to the hatching muscle. In all the species the lateral lymph areas were present, though small, at the time the hatching muscles became distinct to the unaided eye.

The first intimation of actual movement of lymph into the muscle was a change in the color of segment 1. This happened in the various species at the following body weights: Blue-winged Teal, 7-8 grams; Shoveler and Pintail, 9-10 grams; Gadwall, 13-14; Mallard, 10-12; Redhead, 15-20; and Ruddy Duck, 20-25 grams.

The medial lymph spot appeared in each species when body weights were 2 to 5 grams greater than those just given. With increased age the spot elongated and broadened and extended posteriorly between Mm. biventer cervices and Mm. complexi. For example, in the Blue-winged Teal it sometimes formed a band 2 mm. by 6 to 10 mm. at the prepipping maximum. It disappeared near the end of the pipping activity, during hatching, or within 36 hours of hatching.

Extraordinarily rapid changes in the lateral lymph areas also took place. Those changes in the Redhead were fairly typical. Data in Table 1 illustrate the continuous and quick increments in size through the prepip stage. What was not evident in this species, but was true of all others, was that the decline in lymph area began during pipping of the egg. In the Ruddy Duck the areas did not exhibit the continuous buildup prior to pipping; most of the increase occurred as body weight increased 5 grams in the prepip stage. The areas in just-hatched ducklings of all species were significantly smaller than in ducklings sampled during pipping. In the week following hatching the areas decreased rapidly, but in the second week they began a second surge of growth observed to continue, at least in the Blue-winged Teal and Mallard, through 30 days of age.

The Ruddy Duck was again an exception. By all relative and absolute standards the areas of lymph in it were very significantly greater than in any other species. Further, the lateral areas invaded the region beneath the outer edges of the hatching muscle just prior to hatching. But, by the fourth or fifth day after hatching, yellow fat replaced most of the lymph and covered the remainder.

Changes in muscle mass. — The data presented for the Redhead (Table 1) were representative of the changes in absolute weights of the hatching muscle and also in the relative weights shown in Figures 3, 4, and 5.

Absolute weights increased during development through the prepip stage, dropped significantly during hatching (particularly in the pipping stage), declined for 3 to 8 days after hatching, and increased thereafter. In the two

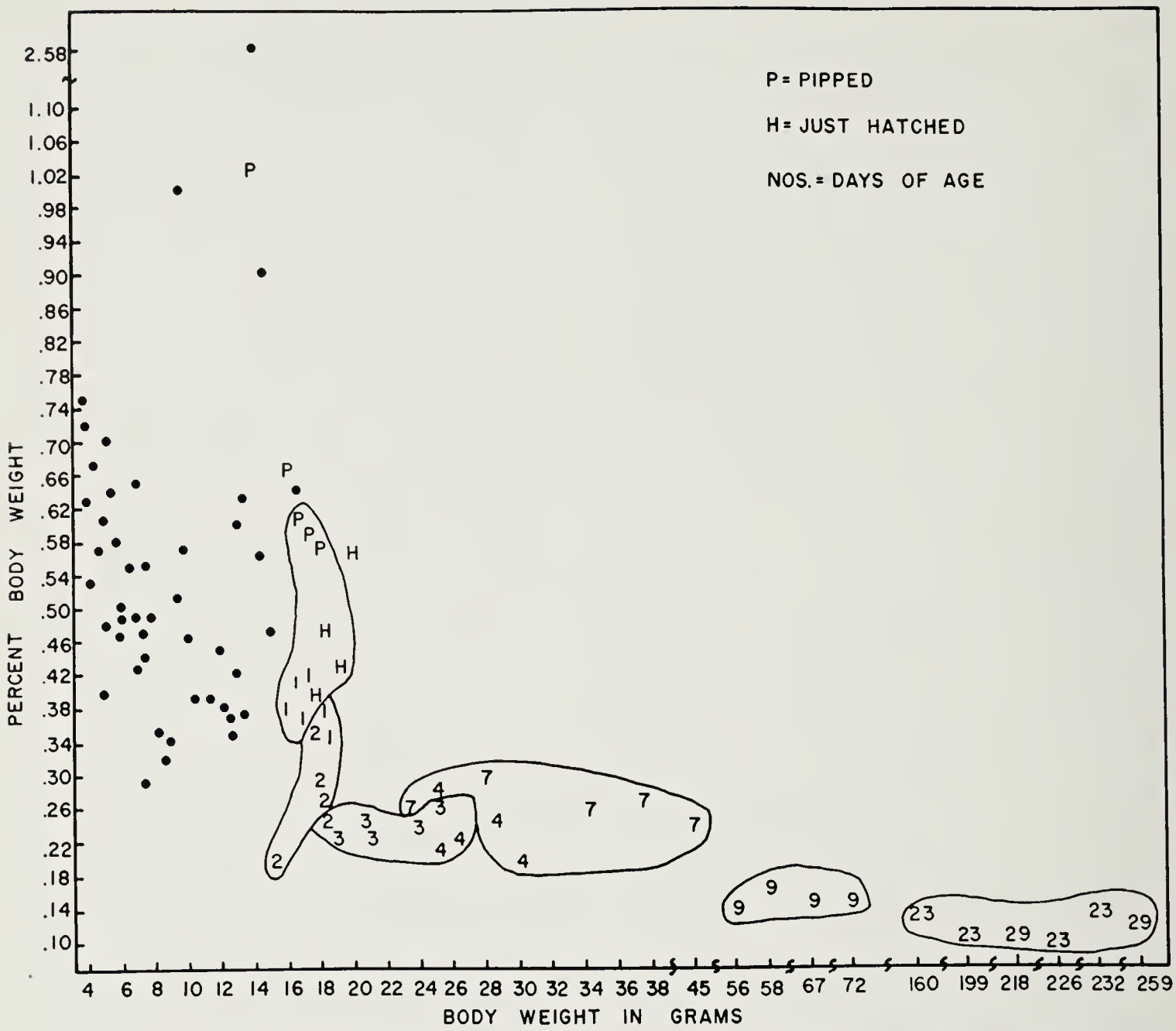

FIGURE 3.—Scattergram showing changes in size of hatching muscles relative to body weights of Blue-winged Teals. (Each encircled group represents a single brood.)

species kept as long as a month after hatching, the muscle was 2.5 times heavier than at pipping in the Blue-winged Teal and twice as heavy in the Mallard. But in the Ruddy Duck at 13 days of age the muscle weight was slightly less than half that at pipping.

The pre-hatching increases were neither steady nor uniform, and they were greater than the relative increments in body weight. Between average body weights in the Redhead of 18 and 23 grams (increase of 28%), muscle weights gained 49%, and when average body weight increased 22% (23- to 28-gram stages) muscle weights went up 55%. The major gains took place during the prepip phase; body weight went up 25% and the muscle weight advanced 129%!

A third of the muscle mass was lost before 24 hours of age and another third in the next 24-hour period. The decline in the next few days was slight and even, but by the end of the first week, in the Redhead, the process was reversed and the daily gain in muscle weight was about 15%. The post-hatching loss of weight was slower in the Ruddy Duck; not until 4 or 5 days did the muscle reduce to a third of its mass at pipping.

The relative size of the muscle was studied in two ways: compared to lymph area and to body weight. When muscle weight was plotted against lymph area, it became obvious that the two increased in a straight-line relationship during the period the embryo gained half its hatching weight. However, body weight increased twice as fast as lymph area in the latter part of the incubation period. The post-hatching regression of lymph and muscle was again directly and uniformly correlated, but the fol-

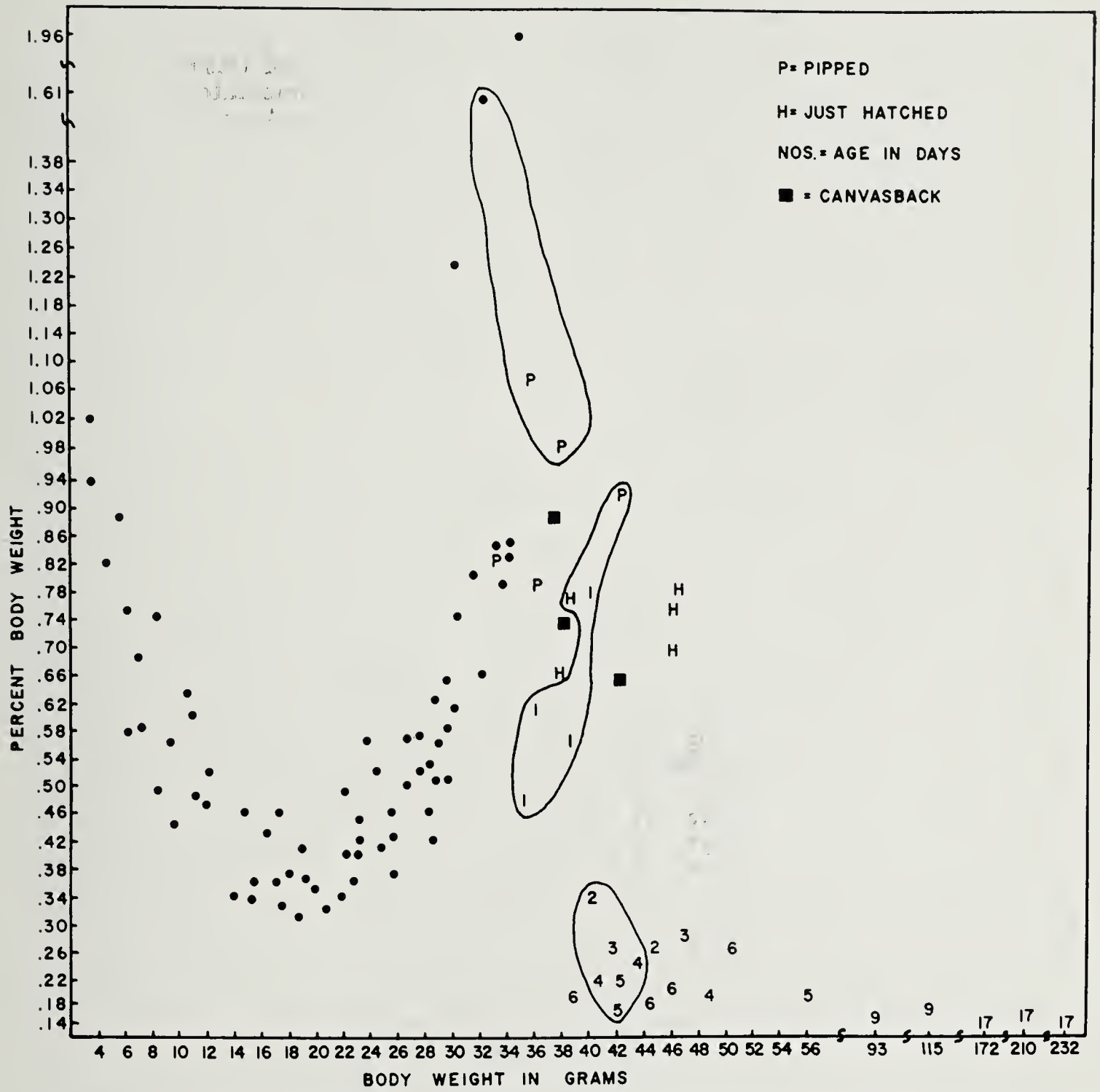

FIGURE 4.—Scattergram showing changes in size of hatching muscles relative to body weights of Redheads. (Each encircled group represents a single brood.)

lowing recrudescence of muscle was much more rapid than that of the lymph area (Fig. 6).

The data in Figures 3, 4, and 5 and Table 1 revealed that, despite a constant, pre-hatching increase in muscle mass, there was in all species a period of decline in the relative size of the muscle that continued until half the hatching weight had been attained. Thereafter the gain in muscle weight was relatively much more rapid than the gain in body weight.

Without exception the greatest relative mass of the muscle was present in the prepip and early pipping stages (Table 2). It was also evident in Table 2 that relative muscle weight dropped markedly during the hatching process in most species, but significant variations did occur in the percentage decrease between the pipping and just-hatched stages. Shovelers and Pintails showed declines during hatching of 48 and 43%, respectively, the Blue-winged Teals 36%, and Mallards and Redheads 22 and 28%. The muscle in the Ruddy Duck did not exhibit this regression between pipping and emergence.

The data indicated that relative muscle size decreased greatly during pipping, at least in some species. (See Pintail, Blue-winged Teal, and Ruddy Duck in Table 2.)

When the gain in relative size of the hatching muscle, from its lowest pre-

hatching level to its mass at the combined pipping and pre-pipping stages, was compared for the species studied, major diversities were revealed (Table 3, top). Gains ranged from 26 to 221%! When percentage increase in relative size was calculated simply as the gain from least to greatest (Table 3, bottom), a similar degree of variation was demonstrated.

Considerable uniformity was exhibited (Table 3), however, in the least relative sizes of the muscle before hatching (0.33-0.43% of body weight) except for the Ruddy Duck (0.59%) and in the relative sizes immediately after hatching (Table 2, 0.44 to 0.54% of body weight) with the exceptions of the Redhead (0.73%) and the Ruddy Duck (0.77%).

The similarity between greatest relative weights of the hatching muscle was not so evident (Table 3); these weights ranged from 0.89% of body weight in

TABLE 1. Quantitative Changes in the Hatching Muscle and Lymph Areas During Development in the Redhead.

N	Body wt. (gms.) or stage	Muscle wt. (gms.)	Ratio, muscle: body wts.	Lymph area (mm^2)
8	6–10	0.047 (0.037–0.063)	0.62 (0.46–0.77)	15
7	11–15	0.062 (0.050–0.070)	0.52 (0.36–0.65)	36
11	16–20	0.068 (0.052–0.082)	0.39 (0.33–0.48)	66
11	21–25	0.101 (0.071–0.137)	0.44 (0.34–0.58)	90
18	26–30	0.157 (0.101–0.231)	0.55 (0.39–0.76)	96
8	Pre-pip	0.360 (0.216–0.655)	1.11 (0.68–1.96)	118
5	Pipping	0.348 (0.282–0.394)	0.94 (0.81–1.10)	121
5	Just hatched	0.308 (0.225–0.375)	0.73 (0.63–0.79)	103
4	1 day	0.241 (0.174–0.322)	0.63 (0.50–0.80)	86
2	2 days	0.137 (0.128–0.145)	0.32 (0.29–0.36)	57
2	3 days	0.129 (0.119–0.139)	0.30 (0.29–0.30)	78
3	4 days	0.106 (0.096–0.116)	0.24 (0.22–0.27)	41
3	5 days	0.101 (0.084–0.120)	0.22 (0.20–0.24)	25
4	6 days	0.128 (0.080–0.140)	0.23 (0.19–0.28)	25
2	9 days	0.181 (0.152–0.210)	0.17 (0.16–0.18)	63
3	17 days	0.300 (0.239–0.335)	0.14 (0.14–0.15)	75

TABLE 2. Ratio of Weight of Hatching Muscle to Body Weight.

	Pre-pip		Pip		Just-hatched	
	N	Mean	N	Mean	N	Mean
Mallard	3	0.63	6	0.89	4	0.54
Gadwall	6	0.37	2	0.51	1	0.44
Pintail	5	1.24	2	0.89	4	0.51
Blue-winged Teal	4	1.17	5	0.69	5	0.44
Shoveler	4	0.74	4	0.92	2	0.48
Redhead	8	1.11	5	0.94	6	0.73
Ruddy Duck	7	1.03	4	0.73	3	0.77

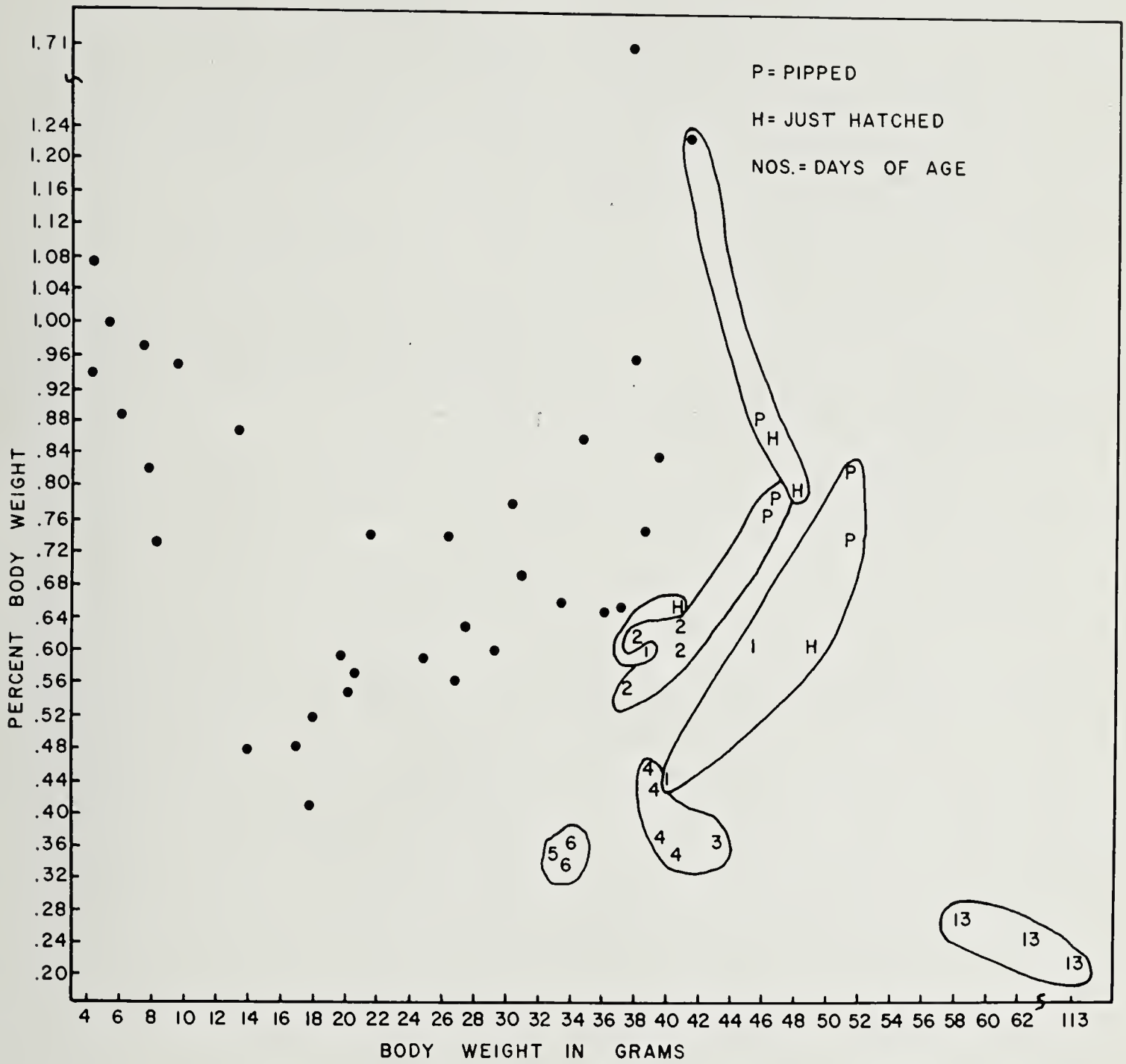

FIGURE 5.—Scattergram showing changes in size of hatching muscles relative to body weights of Ruddy Ducks. (Each encircled group represents a single brood.)

the Mallard to 1.24% in the Pintail, if one discounted the 0.51% in the Gadwall as being based on an inadequate sample.

Within a day or so after hatching, the relative weight of the muscle was at or below its lowest pre-hatching level. The mass of the muscle continued to lose relative size at least for a month in some species. At the end of this time it was down to approximately 0.10% of body weight.

The decline in relative size of the muscle during the hatching process and later was further substantiated by sampling of members of the same clutch or brood which constituted samples that could be expected to be more genetically uniform (Figs. 3, 4, and 5). All 14 broods or clutches of ducks sampled at two or more stages exhibited the decrease.

Body Weight at Time of Pipping and Hatching

The data are in Table 4. It was not possible to attach any significance to increases in weight between the pipping and hatched stages; inclusion of yolk with the latter ducklings may have been responsible for these differences. It was noteworthy that the Mallard and Ruddy Duck exhibited no increase despite the inclusion of the yolk. During sampling it was observed that yolk sacs of the Redhead were much heavier than

those of any other species. Weights of 5 from the Redhead averaged 7.3 grams compared to 4.9 for 5 of the Mallard and 5.4 grams for 4 sacs taken from Ruddy Ducks. The data may mean a slower and later intrusion of yolk in the Redhead and may suggest that these weight relationships of the Redhead should be considered similar to those in the Ruddy and Mallard.

Thickness of Egg Shell at Hatching

The data are in Table 5. The shell in the Ruddy Duck was significantly thickest of the species investigated; that of the Redhead was next thickest. The shell in the Mallard was intermediate to these two species and the Shoveler. There was no significant difference between the Pintail and the Blue-winged Teal which had the thinnest shells.

Hatching Time of Single Eggs

Blue-winged Teal: Of 68 eggs of 7 clutches the shortest time between pipping and emergence was 4.0 hours and the longest was 35.5 hours (mean, 9.0± 1.8).

Table 3. Gain in Relative Size of the Hatching Muscle During Incubation.

	Per cent muscle is of body weight at:				
	N	Pre-pip + pip stages	N	Lowest pre-hatch stage	Per cent of gain
Mallard	6	0.63	6	0.39	62
Gadwall	4	0.44	13	0.35	26
Pintail	4	1.06	6	0.33	221
Blue-winged Teal	9	0.90	8	0.42	114
Shoveler	8	0.85	10	0.43	98
Redhead	10	1.03	11	0.39	164
Ruddy Duck	11	0.92	5	0.59	56

	N	Greater, pre-pip or pip stage	N	Lowest pre-hatch stage	Per cent of gain
Mallard	6	0.89	6	0.39	128
Gadwall	2	0.51	13	0.35	46
Pintail	5	1.24	6	0.33	276
Blue-winged Teal	4	1.17	8	0.42	179
Shoveler	4	0.92	10	0.43	114
Redhead	8	1.11	11	0.39	185
Ruddy Duck	7	1.03	5	0.59	75

TABLE 4. Body Weights in Grams at Pipping and Hatching.

	Pipping			Hatched		
	N	Mean	Range	N	Mean	Range
Mallard	5	36.6	35.5–38.3	4	36.4	34.1–39.2
Gadwall	2	25.8	24.0–27.6	1	26.1	.....
Pintail	2	24.9	20.8–25.1	4	27.9	24.5–30.5
Blue-winged Teal	5	16.1	13.6–17.5	5	18.5	17.3–19.8
Shoveler	6	19.3	17.5–21.8	2	22.1	20.1–24.2
Redhead	5	36.9	33.0–42.1	6	41.8	36.0–46.3
Ruddy Duck	4	48.2	46.3–51.3	3	44.8	40.5–47.8

Redhead: Forty-one eggs showed a mean time of 26.4± 3.1 hours (11-48) from pip to hatch.

Ruddy Duck: Seventeen eggs, in two fresh clutches taken June 10, had a mean time from pip to hatch of 5.6± 0.80 hours (2.5-9.0). Two clutches, incubated less than one week and collected June 23, showed in their 19 eggs a variation from 5.5 to 40.0 hours (mean 12.4± 1.8). In Table 6 is the chronology of a clutch collected on June 23. It illustrated the great diversity in hatching time between eggs of the same clutch and the longer mean hatching time late in the season.

Shoveler: The mean time between pipping and hatching of an egg in a sample of 11 from one clutch was 10.8± 1.1 (7.9-12.2) hours.

Pintail: From pip to hatch required a mean of 12.6± 1.3 hours (8.6-14.1) among 19 eggs of 2 clutches collected in mid-June.

Franklin's Gull: The 20 eggs in the 2-egg clutches showed a mean time from pip to emergence of 8.6 hours (5.5-17.0); in the 3-egg clutches (15 eggs) it was 7.9 hours (5.5-14.5). There was no significant difference in time between first and second or first and third eggs in a clutch.

American Coot: Mean hatching time of 60 eggs was 9.3 hours but the range was very great—4.5 to 20 hours. Eggs in the 8-, 10-, and 11-egg clutches averaged 11.6 hours; in the 14- and 17- egg clutches the mean was 7.9 hours. In all clutches the last half of the number of eggs to pip had significantly shorter hatching times than the first eggs that pipped.

Hatching of Entire Clutches

Blue-winged Teal: Seven clutches had a mean time of 31.4 hours (21.5-38.5) between pipping of the first egg and hatching of the last duckling (hatching time), but all ducklings in a clutch emerged within a span of 11.6±1.3 hours (8.0-16.5) (emergence time).

Redhead: One clutch of 8 hatched within 31 hours. The three other clutches showed times of 39 (12 eggs), 61 (10 eggs), and 72 hours (11 eggs). The ducklings of the first clutch (early June) emerged within a 10-hour period, the second set in a 24-hour span, the third set within 46 hours, and the time from first to last emergence in the last clutch (third week of June) was 60 hours. In Table 7 are data indicating that in a clutch the hatching was quicker in eggs which start the process later.

Ruddy Duck: Four clutches with a total of 36 eggs showed a mean hatching timespan of 18.4±2.1 hours (10.5-40.0) between pipping of the first egg and emergence of the last duckling. However, if the clutch with the 40-hour span was eliminated, the data were: mean, 14.6±0.8; range, 10.5-22.0. The two clutches (17 eggs) of June 10 showed a mean time of 13.6 hours (9.3-13.9). The two clutches of June 23 (19 eggs) took an average of 23.2 hours.

TABLE 5. Thickness of Egg Shell (Ten-thousandths of an Inch) at Hatching.

	N	M
Ducks		
Mallard	9	111±2
Pintail	11	78±2
Blue-winged Teal	45	75±1
Shoveler	13	83±1
Redhead	37	129±2
Ruddy	29	142±2
Franklin's Gull	18	72±4
American Coot	34	105±1
Grebes		
Horned	3	77±3
Eared	4	88±1
Pied-billed	8	91±2
Red-necked	2	97
Western	4	126

Shoveler: The one clutch of 11 eggs emerged in 11.5 hours, but the hatching time was 17 hours.

Pintail: Two clutches (11 and 8 eggs) emerged in 12.5 and 13.5 hours. Elapsed time between pipping of the first egg and hatching of the last egg was 16.5 (11.0-22.0) hours.

Franklin's Gull: Ten clutches of 2 eggs each showed mean emergence times of 24.3 hours (18.0-27.5), and 5 clutches of 3 eggs each had elapsed times of 46.0 hours (40.5-57.5). Hatching times for 2-egg clutches averaged 31.4 hours (26.5-36.5); for 3-egg clutches the times ranged from 58 to 72 hours (mean, 61).

American Coot: Because the number of eggs was so different in the various clutches, no numerical means for hatching and emergence times were calculated. Hatching times by clutches were: 8 eggs, 6 days; 10 eggs, 8 days; 11 eggs, 9 days; 14 eggs, 10 days; and 17 eggs, 12 days.

Fertility and Hatchability

Blue-winged Teal: No infertile eggs were found among the 123 incubated. Six eggs failed to hatch; one was from a partly incubated clutch of 8 collected June 3, 2 from a fresh clutch of 7 taken on June 21, and 3 from a clutch of 9 that had been incubated for perhaps 5 days before being collected on July 5.

Redhead: Of 117 eggs taken from 3 dump nests 61 were infertile. Thirty embryos died within seven days after being placed in the incubators; these deaths occurred in three different incubators and at body weights varying from 3.6 to 31.0 grams. Forty-one of 43 eggs from "clean, down-covered" nests hatched; one egg was infertile and one embryo died at 28.5 grams.

Ruddy Duck: All 69 eggs collected were fertile and produced viable embryos to the time of sampling.

Shoveler: Only two of the 57 eggs were infertile and the embryos in all others were viable to the time of sampling.

Pintail: One of 43 eggs was infertile and 2 eggs had dead embryos at the time of sampling (5.8 and 11.4 grams).

Gadwall: Three of 39 eggs were infertile and 5 died during incubation.

Discussion and Summary

The hatching muscle: morphology and segmentation. — As in all birds thus far studied, M. complexus is made up of three segments in ducks; the fourth segment is small even in its occasional occurrence. The conformation, origin and insertion, in general, are the same in the species of ducks studied and closely similar to the hatching muscles in the chick (H. I. Fisher, 1958), in grebes (H. I. Fisher, 1961), the American Coot (J. R. Fisher, 1962), and Franklin's Gull, and the Common and Black terns (H. I. Fisher, 1962).

In all species the first evidence of segmentation is the fibrous line between segments 1 and 2, and it is a curious and thus far inexplicable fact that in all species the segmenta-

TABLE 6. Chronology of Pipping and Hatching Times for a Clutch of Ruddy Duck Eggs Collected June 23.

Egg	First pip	Hatch	Elapsed time (hours)
1	8:00 a.m.—July 20	1:30 p.m.—July 20	5.5
2	7:30 a.m.— " "	11:00 p.m.— " "	15.5
3	8:00 a.m.— " "	3:00 p.m.— " "	7.0
4	5:00 p.m.— " "	8:00 a.m.— " 21	15.0
5	1:30 p.m.— " "	12:30 a.m.— " "	23.0
6	2:00 p.m.— " "	6:00 a.m.— " 22	40.0
7	3:00 a.m.— " 21	10:30 a.m.— " 21	7.5
8	10:00 a.m.— " 21	4:00 p.m.— " 21	6.0
9	1:00 a.m.— " 21	2:00 p.m.— " 21	13.0

TABLE 7. Chronology of Pipping and Hatching Times for a Clutch of Redhead Eggs Collected June 27.

Egg	First pip	Hatch	Elapsed time (hours)
1	3 p.m.—July 23	10 p.m.—July 24	31
2	3 p.m.— " "	10 p.m.— " "	31
3	3 p.m.— " "	9 p.m.— " "	30
4	7 a.m.— " 24	11 p.m.— " "	16
5	8 a.m.— " "	3 a.m.— " 25	19
6	8 a.m.— " "	8 a.m.— " "	24
7	9 a.m.— " "	7 a.m.— " "	22
8	8 a.m.— " "	11 p.m.— " 24	15

TABLE 8. The Relationship Between the Length of the Incubation Period and the Weight of the Hatching Muscle when Segmentation first appears.

	Incubation (days)	Muscle wt. at seg. (gms.)
Franklin's Gull	18–20	.04 – .07
Coot	21	.05 – .08
Shoveler, Blue-winged Teal, Pintail	21–23	.03 – .05
Grebes	22–25	.02 – .05
Gadwall, Mallard, Redhead	25–28	.03 – .06
Ruddy	30	.07 – .09

tion first appears when the embryo weighs 5 to 9 grams, except in the grebes in which it is already present at 2 to 3 grams body weight. Uniformity of time of appearance of muscle segments in a species, within a range of 2 grams of body weight, might be expected, but not in a range of kinds of birds from terns to ducks which vary so greatly in weights at hatching time (Common Tern, 14 gms. versus Ruddy Duck, 45 gms.) and in weights of adults.

It is well known that different kinds of tissue tend to differentiate on topographical and time schedules or patterns. In the present instance the pattern may relate to functional "need" or mass of the structure. We can only speculate on the physiological or morphological basis for "need" at the time of the first segmentation, but we can consider the possibility that when the absolute mass of the muscle reaches a certain level the hatching muscle begins its segmentation in all species. However, segmentation shows first at the following absolute weights of the hatching muscle: —grebes, 0.020-0.050 grams; gull, 0.044-0.070; Gadwall, 0.026-0.049; American Coot, 0.045-0.076; Mallard, 0.031-0.059; and Ruddy Duck, 0.073-0.090, to cite a few examples. First segmentation of the muscle, then, does not occur at a uniform, interspecific biomass of the muscle, and there are the aforementioned facts suggesting that it takes place at a fairly uniform biomass of the embryo, except in grebes.

Nor is there any evidence that this event correlates in any way with attainment of a certain proportion of adult weight or of hatching weight.

It is also possible, even likely, that time of segmentation is related to total period of development, that is, the incubation period. If this be true, segmentation of the hatching muscle would follow the general pattern of functional development of vertebrates illustrated, for example, by the fact that the heart first begins to beat in such diverse organisms as the chick and the human when approximately one-tenth of the embryonic period for the organism has elapsed.

We may arrange the species by reported incubation periods (Table 8) to show that there is among the ducks a rough correlation between the weight of the hatching muscle at the time of first segmentation and the length of the incubation period. However, the grebes are still an exception, and the coot and gull relate more closely in size of muscle to the larger ducks with longer incubation periods than they do to the small ducks that have periods similar to those of the coot and gull.

Segmentation is completed relatively quickly, with an increase usually of only a gram or two in body weight, except for segment 4 which first appears to the unaided eye at the prepip stage.

The segments retain throughout their existence a cline of decreasing size from anterior to posterior, but in the pre-hatching period absolute size increases in all dimensions. Most marked are the mediad extensions which bring into midline contact the comparable segments of the two sides and hide from dorsal view the underlying biventer cervicis and spinalis muscles. The contact first occurs between the segments of pair 1, shortly after the first indications of segmentation, and progresses posteriorly until at the time of pipping or hatching the muscles of the two sides touch throughout the length of their medial edges in most duck embryos, as they do earlier in development. This is the pattern, with minor variations, in half of the ducks investigated; the Gadwall exhibits much less medial contact and is extremely variable in this regard.

Initial separation of the pair of muscles begins prior to or at the time the first muscle segments appear in the Blue-winged Teal, but in the other species that show this disjunction it takes place later. In the Redhead the muscles in only a few embryos are apart before hatching, and in the Mallard and Ruddy Duck there is no separation during embryonic development. It is believed the absence of initial separation is a correlate of the inherently larger muscle mass and the thicker egg shells in these species, as will be discussed later.

After hatching, regression of the muscle results in permanent loss of medial contact. The time this second separation occurs is highly variable interspecifically—at 4 or 5 days of age in the Blue-winged Teal, at 2 days in the Shoveler, before the end of the first day in the Redhead, and as long after hatching as 13 days in the Ruddy Duck and nearly a week in the Mallard. The possible significance of the variation will be discussed in connection with changes in total muscle mass.

The second most noticeable change in segment size during the embryonic phase is increased thickness due in large part to the infiltration of lymph although, as I indicated in 1958 for the chick, there is some increase in the number and size of the muscle fibers. So great are the turgidity and mass produced by lymph in the muscle that segmentation is only faintly visible or completely hidden in the prepip or pip stages.

After hatching and the depletion of the lymph through use as a nutrient for muscular activity (George and Iype, 1963) or perhaps as a result of its being forced out by powerful contributions of M. complexus,

segmentation reappears temporarily and the segments are thin. By the end of a week only traces of segmentation are visible in such ducks as the Blue-winged Teal and Shoveler; traces persist for as long as 13 days in the Ruddy Duck, 22-30 days in the Mallard, and 14-19 days in the Redhead. It appears that the retention of segmentation, in these latter species, is still another correlate of larger muscle mass and thicker egg shell.

The infiltration of lymph. — The evidence for the filtration of lymph into the hatching muscle in ducks, as in coots, gulls, and chickens, is strong, though presumptive and unquantified. Even in the grebes in which I (1961) found no lymph areas comparable to those of ducks and in the American Coot where J. R. Fisher (1962) reported only scattered kernels or lobes of lymph glands, the muscle assumes a yellowish, lymph-color prior to hatching and is filled with a thin viscous fluid that pushes apart the muscle fibers (H. I. Fisher, 1958).

The changes in the sizes of the lymph glands and the hatching muscles in chicks are directly correlated, in almost a straight-line relationship during the first two-thirds of prehatching development (Fig. 6, Table 1). Increases in lymph area in this time are greater than those in muscle size and tend to precede the latter. In the phases just before prepip, muscle size increases more rapidly than lymph area, perhaps indicative of a more rapid movement of lymph from lymph area to muscle than from the body as a whole to lymph area. With the exigencies of hatching over, absolute muscle size and lymph area regress equally until approximately two weeks of age, at which time both increase; but muscle size increases more rapidly than lymph area (Fig. 6).

Mass of the hatching muscle. — Size of muscle relative to embryo weight follows in ducks the pattern established by previous studies for other species. After a period of early development in which the muscle is relatively very small because of

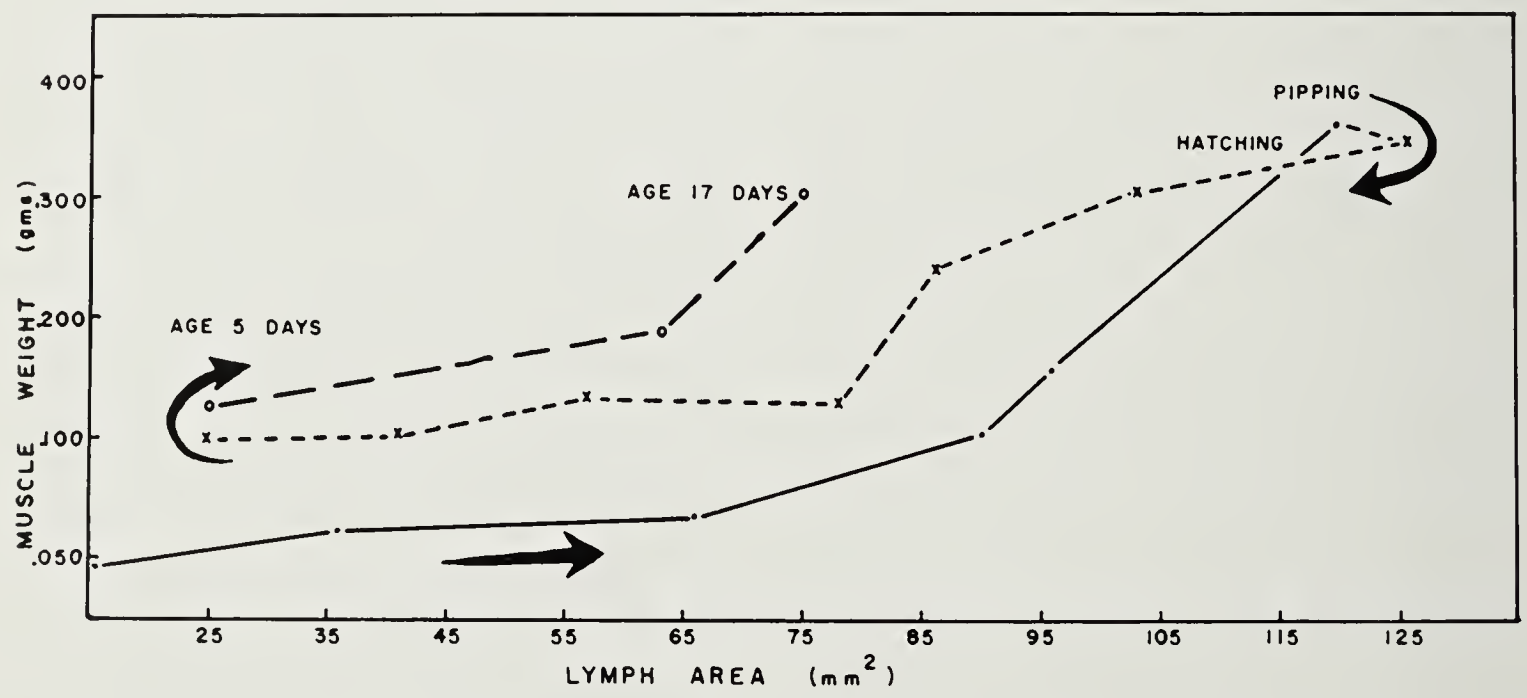

FIGURE 6.—The relationship between actual weight of the hatching muscle and area of lymph during three periods of change in the Redhead.

the greater size of the anterior part of the embryo, the muscle gains in relative size until the prepip or early pipping stage. The greatest relative size the muscle ever attains is variable interspecifically, ranging from 0.51% of body weight in the Gadwall (small sample) to more than 1.0% in the Pintail, Blue-winged Teal, Redhead, and Ruddy Duck (Table 3). In most of the species of ducks, however, the muscle may well constitute 1.0±% of body weight, which is considerably less than in the American Coot (1.20%, 1.12-1.64) or the chicken (1.93%, 0.70-3.41) but more than in grebes (0.65-0.90%) or gulls and terns (0.80-1.0%). In this same table are data showing that the pre-hatching gain in relative size from the prenatal low is also variable, from 46 to 276%.

It is difficult to explain these interspecific variations in relative mass. They do not correlate with differences in weight at hatching; the Ruddy has a muscle equal to 1.0% of body weight and hatches at 45 grams, while the Pintail's relative muscle weight is 1.24% and it hatches at 28 grams. Comparison of weight of adult birds and of hatching muscles indicates no correlation; the light-weight tern and gull have hatching muscles the relative size of those in the Teal and the Mallard, and the Mallard, despite an adult weight approximately the same as the Redhead's, has a muscle one-fifth to one-fourth smaller.

Although the muscle shows continuous gains in actual weights, it is just previous to pipping that it reaches its maximum. In the day or so previous to the first pip of the egg the muscle may double in weight, but once pipping starts the muscle usually fails to gain weight and, most often, begins to shrink. During hatching the loss in muscular weight increases; in the 24-hour period after emergence one-fourth to one-half the mass disappears, and in the next day a similar, proportional loss occurs.

All these rapid fluctuations are caused by the movement of lymph into or out of the hatching muscles. It is not until after the post-natal low that the muscle begins to add weight in normal fashion and to proceed to its adult function of extending the head.

Thickness of egg shell. — Thickness of egg shell might be judged to be a factor at least partly influencing the power of the mechanism designed to break the shell, although to demonstrate any certain relationship would require very large samples since it is known in chickens at least (Romanoff and Romanoff, 1949: 115, 116, 119), that there is great individual variation in the shells within a species and even in the shells of the eggs laid by the same individual. Further, there is increased fragility with incubation and changes in organic and inorganic constituents, the kind and extent of which are largely unknown in wild birds.

Study of the data in Tables 3 and 5 reveals no correlations in ducks between thickness of shell and relative size of the hatching muscle; the Blue-winged Teal, for example, has a relatively larger muscle but a thinner shell than the Shoveler, Mallard or Redhead. However, there is a rough correlation between shell thickness and actual weight of the

hatching muscle. The Ruddy and Redhead have the heaviest shells and muscles weighing 0.35 and 0.36 grams, respectively. The Mallard has the next thickest shell and a muscle of 0.32 grams, and the Blue-winged Teal has the smallest muscle (0.11 gms.) and thinnest shell. The Shoveler has a shell heavier than the Blue-winged Teal's and a larger muscle (0.14 gms.). Only the Pintail, of the ducks whose shells were measured, does not conform; its shell is 0.0078 inches thick, intermediate to the Shoveler's and Teal's, but its muscle is nearly twice as heavy (0.22 gms.).

The Coot, however, has a shell 0.0105 inches thick and a muscle of only 0.19 grams or approximately half as large as the Mallard which has essentially the same thickness of shell; it does not fit into the duck series. Kortwright (1943:233) noted the exceptional hardness and toughness of the egg of the Redhead, and I suggested (1961:233) that eggs of grebes were, as compared to other species of water birds, soft and rather easily broken and that some of the difference in these features within the grebe group might relate to the differences in the amount of wet vegetation the various species used to cover the eggs when the incubating birds left the nest.

Subsequent measurement of shell thickness in the grebes (Table 5) showed by far the heaviest shell in the Western and the next thickest in the Red-necked, but the muscle was larger in the latter. However, both these grebes had muscles twice as large (0.16-0.24 gms.) as those in the smaller grebes (0.08-0.09 gms.), all of which had significantly thinner-shelled eggs. Thus, within the grebes as in the ducks there is a gross correlation between size of hatching muscle and thickness of egg shell.

Franklin's Gull has a muscle of 0.17 grams, and its shell is comparable in thickness (0.0072 inches) to that of the Blue-winged Teal which has a muscle of 0.11 grams. Moreover, the teal's egg is laid on land and might be presumed to be harder than the gull's egg which lies on a water-soaked mat of vegetation.

If one plots relative muscle size against presumed place in avian phylogeny, the factors determining muscle size are even less understandable. It is obvious that genetic and environmental factors, such as humidity in the nest, are interacting and that no one-line, simple correlation is present.

Body weight at hatching. — Absence of any increase in body weight between the pipping and hatching stages in the Mallard, Ruddy Duck, and perhaps in the Redhead, may be related to two factors: 1) There may be a greater utilization of energy in pipping and cracking the thicker shells in these species; or 2) there may be a difference in the time at which the yolk sac is intruded. If the yolk enters the body early in the pipping process in the Mallard and Ruddy and much later in the others, especially the Redhead, it could be the sole factor.

If the few data on weights of yolk sacs are truly significant, and if the differential comparison between these weights for the Redhead, Mallard and Ruddy Duck are valid, they suggest that ducklings weighing approximately 40 grams at hatching may expend the equivalent energy

of 2 grams of body weight in freeing themselves from the egg.

Hatching weight equals: 2.8 to 3.0% of adult weight in the Mallard, Gadwall and Pintail; 3.4 and 3.7 in the Shoveler and Redhead, respectively; 4.3% in the Blue-winged Teal; and 7.3 in the Ruddy. Thus, there is no direct correlation between hatching weight and adult weight.

Hatching time: single eggs. — The fact that all eggs were artificially incubated may have influenced the actual time required for a duckling to emerge after the first pip of the egg, but since all eggs used in this part of the study were incubated under the same conditions the relative times are considered valid.

Eggs pipped first at any time of the day and ducklings emerged at random times; no diurnal rhythm was observed in either process.

Blue-winged Teals hatch most rapidly, in less than half the time required by their not-too-distant relatives—the Shoveler and the Pintail—whose eggs have comparable shells. Of the five species of ducks whose hatching times were studied, the Redhead had the longest period (26.4 hrs.), and the Ruddy Duck, which hatches at nearly the same body weight and has a somewhat thicker shell, emerges in 5.6 hours. Since the species of the "teal group" nest under similar conditions and the Redhead and Ruddy in nearly identical situations, the differences in hatching time do not appear to be the result of different environmental factors. Nor are they apparently related to shell thickness, egg size, body weight at hatching or adult weight.

There is some indication in the Ruddy Duck and in the Redhead that embryos from eggs laid late in the season may take longer in the emergence process, but the data are few. Until a greater series of species and of individuals are studied early and late in the season it is impossible to generalize.

Eggs in two-egg clutches of Franklin's Gull had a mean hatching time of 8.6 hours which is not significantly different from the 7.9 hours required by eggs in 3-egg clutches. Times for first and last eggs that pipped were not different.

In American Coots, the hatching time of individual eggs appears to vary with the number of eggs in the clutch; eggs in clutches of 8 to 11 eggs hatched in 11.6 hours and eggs in 14- to 17-egg clutches averaged only 7.9 hours. Further, within the clutches there was a cline of hatching times; the first eggs to pip had significantly longer hatching times than did the eggs that pipped later.

Hatching time: entire clutch. — Two aspects are of importance here. First is the total elapsed time between pipping of the first egg and emergence of the last one (hatching time). The second is the time between emergence of the first and last ducklings from a clutch (emergence time).

The Blue-winged Teal and Redhead had total hatching times of 31 hours, the Ruddy 18 hours, and the Shoveler and Pintail approximately 17 hours, in clutches laid throughout the month of June. However, late-June clutches of Redheads and Ruddies had significantly longer times. Whether this was a direct seasonal

effect or the result of more than one female laying in a nest, a habit these species have, is not known.

The period in which the ducklings emerged was much more uniform, within and between species, and much shorter than total hatching time. Further, the chronologies of the hatching of individual clutches of duck eggs and of clutches of American Coot eggs showed that in most instances the first eggs to pip took the longest time to emerge. This was not true for clutches of Franklin's Gulls, however. Thus, the evidence, though scanty, indicates, as Vince (1964, 1966) has suggested, that in precocial species emergence of the young from late-pipping eggs is in some way speeded-up, perhaps by the activities of the early-pipping embryos. The evidence from five clutches of Coot eggs further suggested that the facilitation might be, in part at least, a function of clutch size.

Obviously, any shortening of the emergence period in precocial birds means greater survival. If it is generally true for ducks that emergence time increases with season (Redhead —10, 24, 46, and 60 hours), the decreased survival might be a major factor in limiting the length of the breeding season and in explaining why re-nestings in ducks are not too frequently undertaken.

Fertility and hatchability. — Of 374 eggs taken from normal nests only 7 eggs proved to be infertile (3 Gadwall, 2 Shoveler, 1 Pintail, and 1 Redhead). The overall infertility rate was 1.9%, but it varied interspecifically; it was zero in 123 eggs of Blue-winged Teals and in 69 of Ruddies, but approached 8% in Gadwall eggs.

Gadwalls also had the highest rate of deaths of embryos (13%). All fertile eggs of Ruddy Ducks hatched. Hatchability appears to decline with the season, if the series of eggs of Blue-winged Teals is typical.

However, these are but straws of evidence and until large-scale controlled experiments are undertaken we can draw no conclusions. We know little or nothing of the effects at different stages of incubation of humidity, intermittent cooling, agitation or movement of eggs as in moving them from field to laboratory, or indeed of the temperatures most suitable for each species.

General comments. — Although the study was not designed to bring out taxonomic differences and members of only three subfamilies were represented, some differences may be mentioned.

The Ruddy Duck (subfamily Oxyurinae) in its hatching mechanism varies markedly from the ducks representing the Anatinae and the Aythyinae. The muscle is always—prenatal, at hatching and post-hatching—significantly largest. The muscle shows the least relative losses in weight during the hatching process. No fourth segment is present. Lymph moves into the muscle much more rapidly and later, and there is greater infiltration of lymph into tissues surrounding the hatching muscles. Only in the Ruddy are the lateral lymph areas covered by yellow fat in the immediate post-hatching period. Regression of M. complexus is slowest; medial contact between the muscles of the two sides is main-

tained for at least 13 days, and the muscle loses less weight and more slowly. The shell of the egg is significantly thickest and, of course, the egg is the largest.

The Redhead, representative of the Aythyinae, demonstrated no constant differences from the five species of the Anatinae, and we may conclude that these two families are more closely related to each other than either is to the Oxyurinae, insofar as the hatching mechanism is concerned.

Acknowledgments

The work was supported by the Graduate School of Southern Illinois University, the Wildlife Management Institute, and the Delta Waterfowl Research Station.

My sincere appreciation goes to my wife, Mildred, and my son, James, for unflagging aid in the field and laboratory parts of the investigation and to Mr. H. Albert Hochbaum, Director, Delta Waterfowl Research Station, for so kindly placing at my disposal the facilities of the Station.

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Manuscript received July 20, 1966.

EFFORTS TO PREVENT THE EXTINCTION OF THE PRAIRIE CHICKEN IN ILLINOIS

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ABSTRACT. — The decline of the prairie chicken in Illinois is reviewed. Actions to prevent the extinction of the prairie chicken are: formation of the Prairie Chicken Foundation, formation of the Prairie Grouse Committee, purchases of land for nesting sanctuaries, and investigations of distribution, abundance, nesting requirements, and other ecological factors affecting the prairie chicken. Continuation of these investigations, and continuation of land acquisition on an increased scale, are necessary if the prairie chicken is to be saved in Illinois.

At the time of settlement, greater prairie chickens (*Tympanuchus cupido pinnatus*) were well-distributed over areas covered by tall grass prairie in Illinois—about 60 percent of the state (Fig. 1). Yeatter (1943: 378) states that "As the Illinois timberlands were cleared and put under the plow, prairie chickens extended their range into these areas from the adjacent prairies, in which the first settlers had found them. Later, as the prairie sod was broken and grain became common, chicken populations increased enormously throughout the grasslands. The highest populations, resulting from the early development of agriculture, seem to have occurred during the 1860's." Then, as agriculture progressed from the early stages, primarily into intensive grain farming, numbers of prairie chickens began to decline. Leopold (1931:165) concluded that the prairies of Illinois "had in 1874 just passed their prime as chicken

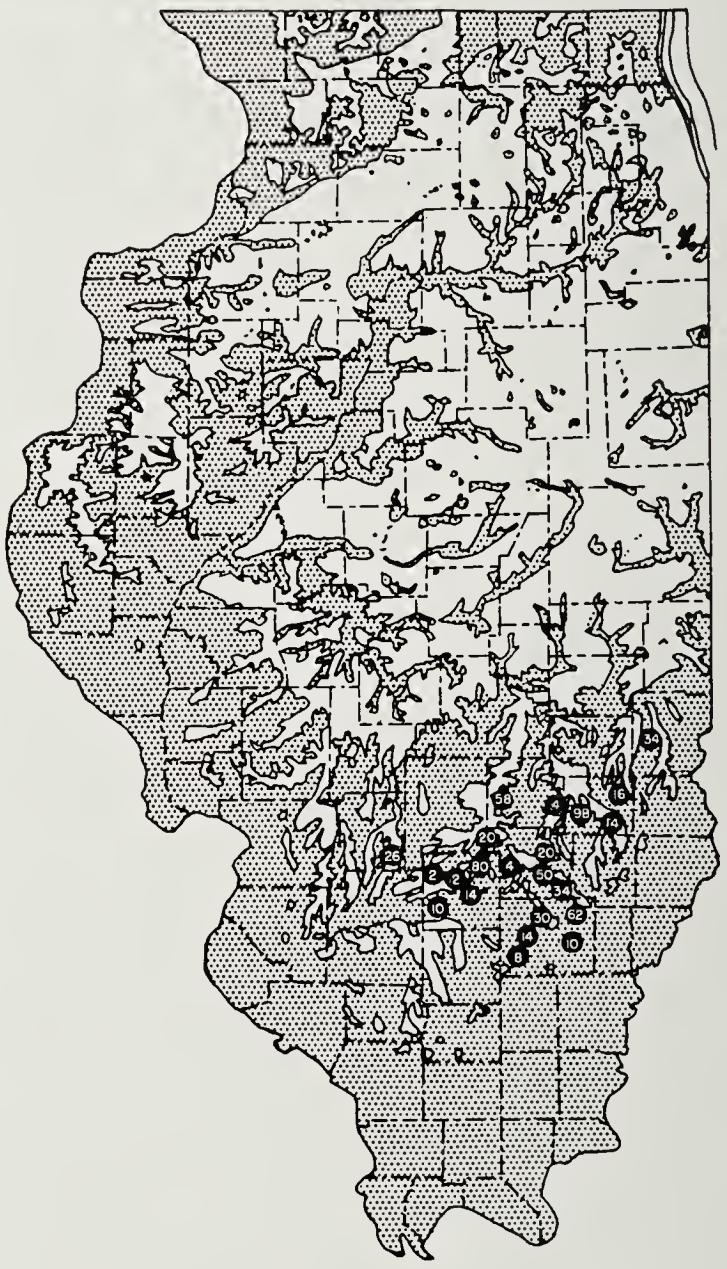

FIGURE 1. — Estimated numbers of prairie chickens on 11 census areas in the spring of 1965 (Westemeier 1966: table 1) in relation to the original prairie vegetation (unshaded portion of map). Map reproduced from Telford (1926:v).

country.'' The Illinois State Legislature, on June 9, 1887, passed game laws that included a closed season on prairie chickens during 1887 and 1888, thus indicating concern over the decline in abundance of these birds.

At the turn of the century, prairie chickens were still well distributed over the Illinois prairie but were found only locally and in greatly reduced numbers (Yeatter 1943: 378). In 1903, the hunting season on prairie chickens, then 30 days, was closed and hunting was not again legalized until 1911. Beginning in 1911, seasons of 5 to 15 days with a daily limit of three birds were tried until 1933. The hunting season on prairie chickens was closed in 1933 and has remained closed. Nevertheless, chicken numbers have continued to decline.

Forbes (1912:47-48) reported that prairie chickens were present in at least 74 counties, ''so abundantly in some that farmers are beginning to protect against their future increase because of the amount of grain which they devour.'' Leopold's (1931:163) map showed no colonies in the prairie soils area west of the Illinois River, but did indicate that local colonies were still present in east-central, northern, and southeastern counties. The period from 1930 to 1935 saw the disappearance of nearly all remaining colonies in the east-central counties and a reduction in numbers of prairie chickens in the northeastern marshlands. One of the last flocks in central Illinois was present on the University of Illinois south farms until 1932 (Yeatter 1943:379).

In 1940, the range of the prairie chicken in Illinois was reduced to 50 square miles of sand prairie along the Green River in Lee County and about 2,600 square miles of gray prairie in the southeastern counties, and there were a few scattered flocks in poorly drained areas in northern Illinois in the Kankakee drainage (Yeatter 1943:379). The last prairie chickens—the Lee County flock—probably disappeared from northern Illinois about 1960 or shortly thereafter.

Before the use of modern techniques of fertilization and land management, the gray prairie soils of southern Illinois were poorly drained, strongly acid, and low in productivity. The chief crop was redtop grass (*Agrostis alba*) grown principally for seed. In 1934, about 85 percent of the world production and 95 percent of the U.S. production of redtop seed was produced in southern Illinois (Burlison et al. 1934, in Yeatter 1943:381). Redtop grown for seed provided nesting cover for prairie chickens and was unquestionably the factor most responsible for maintenance of prairie chickens over much of southern Illinois during the 1930's and 1940's.

In the years since World War II, there have been tremendous changes in the land use of southern Illinois, perhaps best described as successive waves of tractors, limes, fertilizers, and soybeans, followed by herbicides and pesticides. The result has been a change from a grass to a grain economy and a loss of nesting cover. A census of prairie chicken flocks in 20 counties in Southern Illinois during October and November

1962 revealed 179 individual flocks containing approximately 2,000 birds (Ellis 1964:5). This census was based on questionnaires distributed by the Natural History Survey to vocational agriculture students living in 47 high school districts where prairie chickens were thought to occur. With normal winter mortality, this number was down to about 1,000-1,100 birds by the spring of 1963. By the spring of 1964, an additional 20 percent reduction in the population meant that no more than 800-900 prairie chickens were present in Illinois. No more than 500 to 600 prairie chickens existed in Illinois in March 1965 (Fig. 1) and, as of this writing (March 1966), perhaps no more than 300 to 400 survive.

Recent research by the Natural History Survey strongly suggests that a majority of the few remaining flocks of prairie chickens in Illinois would now be extinct if it were not for the Federal Conservation Reserve (CR) Program initiated in 1958. As a result of this program, many acres of cropland in the gray soils area were retired from cropping and planted to grasses and legumes. These fields provided the nesting cover so critically needed to maintain prairie chickens. Unfortunately for the prairie chicken, the CR Program is fast disappearing. In 1963, the six counties supporting the largest numbers of prairie chickens had 595 CR contracts in effect. In 1964 the number of contracts was reduced to 166; in 1965 only 46 remained.

History of Prairie Chicken Conservation in Illinois

The future, and even the present, of the prairie chicken in Illinois appears grim. What has been done to offset this impending tragedy, what is being done, what must yet be done, and by whom? These questions we will now try to answer.

For many years the Natural History Survey has studied and accumulated data on ecology and status of prairie chickens in Illinois. Forbes (1912: 40, 47-48) commented on the status of the prairie chicken and other of our native fauna as early as 1912. Dr. Ralph E. Yeatter began work on the prairie chickens on an area near Hunt in Jasper County in 1936, which he continued until his retirement in 1963. His bulletin (Yeatter 1943) on prairie chickens was one of the first major contributions to the life history and ecology of this species. In conjunction with Dr. V. E. Shelford (Shelford and Yeatter 1955), he reported on suggested relationships between the abundance of prairie chickens and physical factors, especially rainfall and solar radiation. More recently he (Yeatter 1963) reported on population responses of prairie chickens to land-use changes in Illinois.

In the summer of 1962 a cooperative study on the ecology and management of prairie chickens in southern Illinois was instituted by the Survey, the Department of Conservation, and the U.S. Bureau of Sport Fisheries and Wildlife. That fall, Survey biologist Mr. R. J. Ellis was assigned full-time to this project, with headquarters in Jasper County. The study is continuing with Mr. R. L. Westemeier, who replaced Mr. Ellis this past February, as project leader. This research is financed by the Department, under Illinois Federal Aid Project No. W-66-R.

Activities of the Survey biologists have been primarily concerned with (1) determining the annual abundance and distribution of prairie chickens comprising our few scattered remaining flocks, (2) correlating land-use changes with the abundance of prairie chickens, (3) studying the nesting ecology of prairie chickens, and (4) serving as management consultants to the Department of Conservation, the Prairie Chicken Foundation of Illinois (PCFI), and more recently to the Prairie Grouse Committee

of The Illinois Chapter-The Nature Conservancy.

Two particularly noteworthy observations have resulted from the Survey's prairie chicken studies. First, prairie chickens exhibit definite preferences for a certain type of nesting cover—it must be comprised primarily of grasses and there must be a substantial mat of accumulated duff upon which to build the nest (Ellis 1965:7). Second, where the proper vegetative conditions exist, prairie chickens will tolerate relatively high nesting densities. On the Yeatter Sanctuary in 1964 a total of eight nests were found in a 19.1-acre field of redtop seeded in 1962 (Ellis 1965:7).

On the basis of these studies it was concluded that land must not merely be acquired, but that it must be managed to provide quality nesting cover if the chicken is to survive. The ability of chickens to tolerate nesting densities of one nest per 2-3 acres of good habitat suggests that in Illinois a flock can be saved by providing it with a properly managed sanctuary system of as few as 500 acres in high quality nesting cover in several tracts of 40 to 80 acres each on native range near traditional booming grounds.

Biologists of the Survey, as well as wildlife specialists of the Department of Conservation, also participate regularly in the activities of the Prairie Grouse Technical Council. This is a group comprised of biologists representing various states and Canadian provinces actively engaged in research and management of prairie chickens and other native prairie grouse. Working meetings of technicians were initiated in 1957 under the auspices of the National Wildlife Federation in response to the critical or near critical status of the prairie grouse throughout most of their range. Council meetings are held about every 2 years; Illinois will be host state for the next meeting, the seventh, scheduled for September 1967. The purpose of these meetings is for researchers and managers to exchange information on recent experimental findings and new management concepts.

Private groups of conservationists have been and are now actively cooperating with the Illinois Natural History Survey and the Illinois Department of Conservation in the fight to save the prairie chicken. At a meeting of the Illinois Natural Resource Council in the fall of 1958 the necessity of forming an organization to preserve Illinois' native prairie chickens was expressed. A year later, on September 25, 1959, bylaws were adopted and the Prairie Chicken Foundation of Illinois (PCFI) became the first group, public or private, in this state, organized with the single objective "to preserve and perpetuate the prairie chicken."

The parent membership of the PCFI was composed of the Illinois Audubon Society, The Izaak Walton League-Illinois Division, The Illinois Federation of Sportsmen's Clubs, and The Illinois Chapter-The Nature Conservancy. The charter of the PCFI called for a managing Board of Delegates to be comprised of three members selected by each of the four parent organizations—a total of 12 delegates. On March 2, 1966, the Field Trial Clubs of Illinois became the fifth sponsoring member of the PCFI.

The stated goal of the PCFI for the first 5 years was to raise funds adequate to acquire a sanctuary system of 1,000 acres located in the best area of prairie chicken range then remaining in Illinois. On the basis of censuses and field work of Dr. Yeatter and of wildlife specialists of the Department of Conservation, areas near Hunt and Bogota in Jasper County, near Farina in Marion County, and in the vicinity of Clay City in Clay County were considered to have the best potential as sites for future sanctuaries (Fig. 1).

On May 24, 1961, an option was taken by the PCFI to purchase a 77-acre tract, the N ½, NE ¼, Section 28, T. 6N, R. 9E, Jasper County (Fig. 2). The deed for this property was dated May 1, 1962, and was recorded on May 15, 1962. In recommending purchase, Dr. L. J. Stannard reported he had been informed that 68 cocks had been booming there that spring. This tract of fertile, well drained, gray prairie was purchased for $225.00 per acre. It was subsequently dedicated "The Ralph E. Yeatter Sanctuary" in honor of Dr. Yeatter's many years of research on the prairie chicken in Illinois.

On December 17, 1963, a second option was taken on a 20-acre tract (Fig. 2). This tract, the W ½, SW ¼, SE ¼, Section 28, T. 6N, R. 9E, was acquired at a cost of $275.00 per acre, and, although the cost per acre was higher, the quality of the land was not as good as that on the Yeatter Sanctuary. The deed for this property was dated February 17, 1964, but was not recorded until June 26, 1964. This tract was dedicated "The Max Mc-

Graw Sanctuary" in honor of one of the early contributors to the PCFI.

In July 1964, the PCFI acquired control of a third tract, the SE ¼, NW ¼, and the W ½, SW ¼, SW ¼, Section 27, T. 6N, R. 9E. This 60 acres is being purchased on a 10-year contract at a cost of $300 per acre. It is centrally located in Section 27, east of the Yeatter and McGraw Sanctuaries (Fig. 2). This tract was dedicated "The Donnelley Sanctuary" in honor of the efforts of Messrs. Gaylord Donnelley and Elliott Donnelley in behalf of the prairie chicken.

The most recent acquisition was an 80-acre tract, the NE ¼, SW ¼, and the SE ¼, NW ¼, Section 4, T. 5N, R. 9E, purchased by Mr. Jameson McCormack on November 1, 1965, for $25,000 and leased to the PCFI at a cost of $750.00 per year (Fig. 2). Mr. McCormack paid $400.00 per acre for 10 acres of good prairie soil and $300.00 per acre for 70 acres of less desirable agricultural land. Provisions of the lease stipulate that it is for a period not to exceed 25 years, or until the death of Mr. McCormack and his wife, if less than 25 years. After this period, the property, plus the money paid for the annual leasing, becomes the sole property of the PCFI. Should the PCFI cease to function, the land and money go to The Nature Conservancy (PCFI 1965:7).

The history of the PCFI points out several things: (1) acquisition of sanctuaries has been slow; after 6 years the PCFI has acquired control of only 237 acres, less than 25 percent of this group's original 5-year objective; (2) to date, only about 70 acres of critically needed, high quality, nesting cover have been developed on the sanctuaries; (3) there has been a dramatic increase in the cost of agricultural land suitable for prairie chicken sanctuaries, from slightly more than $200.00 per acre in 1960 to more than $400.00 per acre in 1965; and (4) the abundance of prairie chickens at Bogota has continued to decline because of a continuing deterioration of habitat conditions over the area as a whole (Ellis 1964).

While the PCFI has done its best to interest others in the plight of the prairie chicken, to raise funds, and to acquire land, their efforts have not been adequate to compensate for the rapid loss of nesting habitat and to assure the

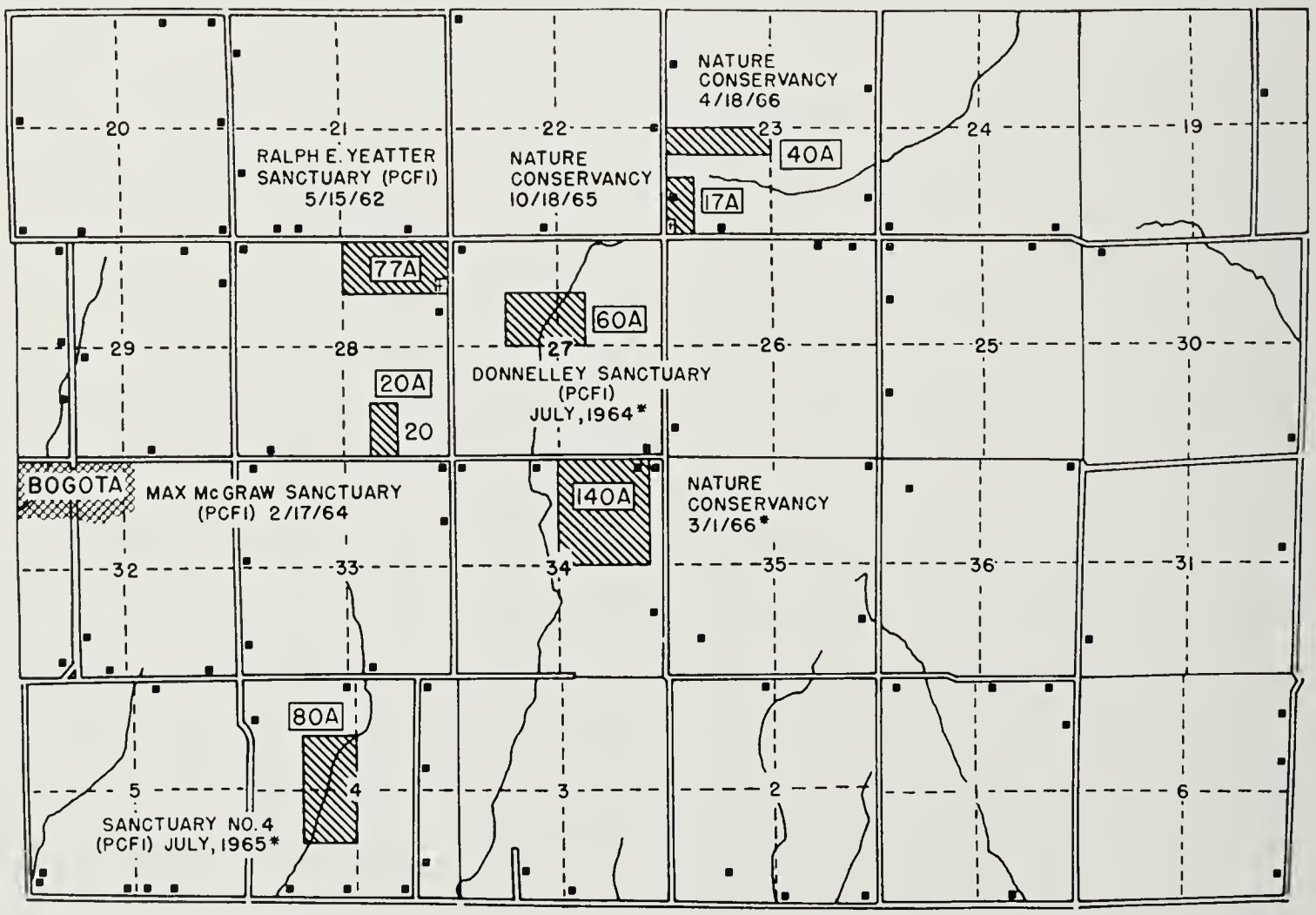

FIGURE 2. — Location of prairie chicken sanctuaries at Bogota in March 1966. *Purchase contract or lease; final transfer of these tracts will be made at future dates.

saving of the prairie chicken flock at Bogota.

Land prices have been rising each year and the prairie chicken population level has been declining each year. The Nature Conservancy, through the leadership of a group of dedicated conservationists from Chicago, with the advice of the Illinois Natural History Survey, has initiated an accelerated campaign to supplement and complement the PCFI's pioneer efforts. The Honorable Otto Kerner, Governor of Illinois, demonstrated his interest in the Nature Conservancy's project by accepting the position of Honorary Chairman of the committee.

Thus, the Illinois Chapter-The Nature Conservancy in the fall of 1965 formed a special Prairie Grouse Committee, to raise $125,000 to purchase 300 additional acres of sanctuaries for prairie chickens. This committee purchased a 17-acre tract, the W ½, SW ¼, SW ¼, Section 23, T. 6N, R. 9E, at public auction for $400 per acre on October 2, 1965 (Fig. 2). The deed was recorded October 18, 1966. A purchase contract for $60,000 for a tract of 140 acres ($428.57 per acre), all but the E 20 acres of the NE¼, Section 34, T. 6N, R. 9E, was signed on March 1, 1966 (Fig. 2). A third tract of 40 acres, the N ½, N ½, SW ¼, Sec. 23, T. 6N, R. 9E, was purchased at public auction on April 9, 1966, for $435 per acre. The deed was recorded April 18, 1966. Together with the 237 acres owned by the PCFI, this brings the total acreage in sanctuaries to 434. This acreage, plus three or four more strategically located 20- to 80-acre parcels, and the development of good nesting cover on all sanctuary land, should be adequate, under present conditions, to save the prairie chicken flock at Bogota.

Unfortunately, good nesting cover for the 1966 nesting season is present on less than 70 acres of the land now in sanctuaries. Although seedings are being made as soon as possible after land is acquired, it takes a minimum of 2 years to obtain the desired quality of vegetation, longer if weather conditions are unfavorable. So even though it appears that the desired acreage is finally being acquired, the necessary grass is still 2 or 3 years away.

Although the immediate goal of 500 acres of managed grassland in a sanctuary system has been proposed to save the prairie chicken flock near Bogota, this is far short of what is ultimately desirable to preserve this species in Illinois. A more realistic, long-term objective would be the development of a 600- to 1,000-acre sanctuary surrounded by 10 to 20 satellite sanctuaries, each 20 to 80 acres in size, distributed over a 10- to 15-square-mile area. To avoid putting all our prairie chicken eggs in one basket, at least three such sanctuary complexes would be desirable. Possible locations for future sanctuary sites are the ranges used by the flock still persisting south of Farina in Marion County and the one northwest of Mt. Erie in Wayne County (Fig. 1).

While the Department of Conservation has not purchased land for sanctuaries, it has played, and will continue to play, an important role in the efforts to save the prairie chicken. As indicated above, wildlife specialists of the Department cooperated with the biologists of the Natural History Survey in the census work done in the late 1950's and early 1960's to locate surviving flocks of chickens. Mr. John Slachter of the Game Division of the Department has from the beginning cooperated in the management activities of the PCFI in both an advisory and physical capacity. As reported earlier, the Department of Conservation provides financial support for the prairie chicken research program conducted by the Natural History Survey and has also supported with small annual grants the studies on artificial propagation and on the growth and development of prairie chickens, which have been conducted at the University of Illinois by Dr. H. H. Shoemaker.

At the request of the PCFI, the Department made funds available for the annual leasing of grass and clover hay from local farmers as a stopgap measure to provide the critically needed nesting cover until it could be provided on permanent sanctuaries. The Department leased 164 acres in 1962 (personal communication from Thomas R. Evans), 233.9 acres in 1963 (Ellis 1964:9), 93 acres in 1964 (personal communication from John Slachter), and 7 acres in 1965 (personal communication from Thomas R. Evans).

Partially because of the high cost of leasing, a minimum of $20.00 per acre per year, and the lack of any permament benefit to the chicken for the money expended, nesting studies were initiated by the Natural History Survey at Bogota in 1963. It soon became obvious that few fields of suitable nesting cover

were available for leasing. Those available were primarily second-year seedings of red clover (*Trifolium pratense*) which lacked the buildup of the duffy vegetative debris preferred by nesting prairie chickens.

A total of 850.7 acres of potential nesting cover systematically searched for prairie chicken nests by Survey biologists in 1963 revealed only two nests in 204.9 acres of unharvested red clover and no nests in 125 acres of red clover which had been harvested (Ellis 1964:7). Although nest densities were low, because of the current relative abundance of this hay type, destruction of nests during mowing and plowing of clover was a major cause of nesting failure, yet leasing of fields of red clover at $20-$30 per acre per year was not justifiable, particularly when densities of only about one nest per 100 acres occurred. This is in sharp contrast to densities as high as one nest per 2.4 acres found in the 19.1-acre field of redtop (Ellis 1965:7) referred to earlier.

The outcome of these nesting studies was the recommendation by Survey biologists that the Department lease only high quality nesting cover, but even more important, that the Department initiate a cooperative land-purchase, land-management program with the PCFI. This proposal called for the PCFI to lease sanctuaries to the Department for the development of high quality nesting and brood-rearing habitat and for the PCFI to use all lease payments to help pay indebtedness on existing sanctuaries and to purchase additional acreages. It was felt that such a program would assure (1) that the money spent by the Department would provide high quality nesting habitat not just for 1 year, but for many years, and (2) that annual lease payments to the PCFI in amounts similar to those spent on leasing in 1962 would allow the PCFI to acquire immediately, and pay for in a 10- to 15-year period, up to 200 acres of additional nesting sanctuaries.

The Department readily accepted this proposal and a lease for $2,000 was negotiated with the PCFI in 1963. The lease was renewed in 1964, but the PCFI elected not to continue the program for more than 2 years.

While we regret that the Department of Conservation has not purchased land for prairie chicken sanctuaries, we recognize that Department funds for land acquisition are limited and are normally expended for multiple-use projects involving activities such as hunting, fishing, water sports, picnicking, camping, hiking, and field trials, most of which would conflict directly with the objectives of prairie chicken management. In fact, although the Green River Conservation Area in Lee County was purchased primarily to save the last major flock of prairie chickens in northern Illinois, the flock could not survive the multiple-use program developed for that area and, as noted earlier, disappeared within a few years.

The Federal Government has played no direct role in attempts to save the prairie chicken although there is some hope for the future—but not the immediate future. Mr. Lester Dundas of the U.S. Bureau of Sport Fisheries and Wildlife has visited southern Illinois to view our remnant prairie chicken range and has discussed the problems of management with specialists from the Department of Conservation. On the basis of this trip, Mr. Dundas recommended that, under the terms of the endangered species bill (H.R. 9424), the Bureau establish a prairie chicken refuge system in southern Illinois. However, such action would be dependent upon funding from the Land and Water Conservation Fund; no money will be available from this fund prior to the 1967 biennium and possibly not then. We must recognize that the prairie chicken is only one of several endangered species and that Illinois is only one of several states where prairie chickens are endangered.

The Cook County Forest Preserve District has become interested in re-establishing prairie vegetation on several large tracts of land which this organization has recently acquired in the Chicago area. As part of their program, they would like to encourage native prairie fauna and flora on these areas and are currently working with Dr. Shoemaker to re-introduce prairie chickens. An initial, small-scale release of prairie chickens reared in pens was made near Barrington in the summer of 1965, but it is too soon to comment on the success of this experiment.

Conclusions

In summary, the remnant prairie chicken flocks are in immediate danger of extirpation. By 1970 the story will be told. Fortunately, the PCFI and the PGC have now acquired 434

acres of sanctuaries and hope to buy more. If high quality nesting cover can be developed on this acreage in the next 2 years, the flock at Bogota should be saved for the present. However, a minimum of two more flocks, probably those near Farina and Mt. Erie, should be provided similar nesting sanctuaries. Ultimately, sanctuary systems should each be comprised of approximately 2,000 acres of managed grassland or prairie distributed in a scatter pattern over 10 to 15 square miles of traditionally good prairie chicken range. At present, chances of immediate participation by Federal or State agencies in a land acquisition program of this magnitude do not appear good. It appears that saving the prairie chicken in Illinois must continue to be the responsibility of private individuals. While the future does not look bright, it does not appear completely dark, thanks to the efforts of the PCFI and the PGC. There is still time to save the prairie chicken in Illinois—but fast action is needed, and that action is the rapid acquisition, quick development, and proper management of nesting sanctuaries.

Acknowledgments

Thanks are due Dr. Lewis J. Stannard for suggestions and editorial assistance and to Helen Schultz for editorial assistance.

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Manuscript received July 15, 1966.

SOME ASPECTS OF GOLDEN MOUSE ECOLOGY IN SOUTHERN ILLINOIS

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ABSTRACT. — A 1-year study of the ecology of the southern golden mouse, *Ochrotomys nuttalli aureolus*, in southern Illinois revealed that honeysuckle thickets, canebrakes, and cat-brier thickets provided suitable habitat. The average home range of five adults was 1.2 acres, and the greatest linear distance traveled by nine individuals averaged 240 feet. Utilization of arboreal nests seemed to lack a definite pattern; this indefiniteness was further complicated by the undetermined degree of usage of ground nests. Main food items identified were small acorns and seeds of poison ivy, bedstraw, and blackberry.

The golden mouse, *Ochrotomys nuttalli* (Harlan), is a rodent of the southeastern United States which reaches one of the most northerly points of its distribution in southern Illinois. The subspecies occurring in Illinois is the Southern Goldern Mouse, *O. n. aureolus* (Audubon and Bachman), which has been recorded from six counties, namely, Alexander, Jackson, Johnson, Marion, Pope, and Union. Many aspects of the life history of the golden mouse have received little attention primarily because it is limited in distribution and population and because it is of little economic value. Thus, the purpose of this study is to bring to light some additional considerations of the life history of this rodent and to augment some aspects which have been studied previously.

METHODS

The Union County Wildlife Refuge, which lies in the floodplain of the Mississippi River less than one mile south of Ware, Illinois, was selected as a study area. Residence was established on the Refuge where field work was carried out from June, 1960 through July, 1961. Of 6200 acres at the Refuge, lakes and borrow pits constitute 460; agricultural land accounts for 2700; and timber, roads, and barnlots constitute 3050. Some field work was conducted at several other sites in Union County and at one area in Jackson County.

Five study areas for live-trapping were established and coded at the Refuge after arboreal nests were found. On Plot 1, 96 traps were placed at intervals of 66 feet in a grid pattern of six rows with 16 traps in each row. On plots 2 through 5, 20 to 30 traps were placed at random near cover apparently suitable for small mammals. Trappings was carried out on one or more of these plots every month except October. A mixture of peanut butter and rolled oats was used as bait. When each small mammal was live-trapped initially, a numbered, monel metal tag was attached to its ear. After tagging, measuring, and recording the sex, age, reproductive condition, weight, molt, and other information, the animal was released at the point of capture. Because Plot 1 seemed to contain the best population of golden mice and afforded certain conveniences, it was considered the primary study area and received most attention.

When nests were located, information concerning occupancy, height from ground, supporting vegetation, diameter, distance to nearest nest, and other data were recorded. Each nest was marked and inspected periodically to check condition and utilization. A total of 34 non-active nests were collected; these

and 14 others collected in 1955 at the Refuge were examined and information concerning food remains, nest materials, and other aspects were recorded. Nests of golden mice were identified on the basis of hair found in the lining; the bright golden mid-portion of each hair was thought to be a reliable criterion for identification. The seed collection of the Cooperative Wildlife Research Laboratory at Southern Illinois University was utilized in identifying food materials.

A total of 14 0.1-acre quadrats were laid out around nests at various areas in Jackson and Union counties. The diameter breast high (d.b.h.) of trees 3.5 inches or more in diameter were measured and the number of each species was recorded. In addition, general notes were taken on species of shrubs, vines, and small trees in or near each quadrat.

Habitat

The golden mouse has been reported in several types of wooded habitat in Illinois. Layne (1958) recorded it in a sumac thicket with a ground cover of broomsedge and in moist woodlots in or near canebrakes or other brushy situations. This rodent has been said to prefer the thick timber bordering cypress swamps (Hoffmeister and Mohr, 1957; Cory, 1912). It has been captured in canebrakes and honeysuckle thickets at Pine Hills in Union County (John Crim, 1960, Personal Communication). Andrews (1963) collected this species from a drainageway in an old field in Pope County; honeysuckle and green brier (cat-brier) were recorded at this site.

During this study, golden mice were usually found in mesic wooded habitats where 36 species of trees were recorded (Table 1). There was a lack of uniformity in size, occurrence, and abundance of the various species of trees in areas sampled. Shrubs commonly observed in or near quadrats were swamp holly, *Ilex decidua*, dogwood, *Cornus* spp., giant cane, *Arundinaria gigantea*, spice bush, *Lindera benzoin*, pawpaw, *Asimina triloba*, and poison ivy, *Rhus radicans* (plant nomenclature after Mohlenbrock and Voigt, 1959). Vines noted often in these areas were grape, *Vitus* spp., cat-brier, *Smilax* spp., Japanese honeysuckle, *Lonicera japonica*, Virginia creeper, *Parthenocissus quinquefolia*, and trumpet creeper, *Campsis radicans*.

Important plants. — In general, golden mouse habitat in southern Illinois may be separated into three categories depending upon the presence of a particular plant species or genus; these are Japanese honeysuckle thickets, canebrakes, and cat-brier thickets. The former two categories are usually distinct entities in which cane or honeysuckle plants are numerous and dominate that particular type of vegetation of which each is a member. Cat-brier often lacked this dominance and abundance in regions where golden mice were found; that is, mice or nests were noted in local areas where cat-brier was rare or absent, but large mats of this vine were always observed in the immediate vicinity. These three plants were rarely found together in any combination. Of the five live-trapping areas, all were located in bottomland hardwood forests with the important understory species being cat-brier on plots 1 through 4 and cane on Plot 5.

The restriction of *O. n. aureolus* to areas containing one of the three plant categories previously described was due in some part to suitable nesting facilities provided by these groups. This is not a complete explanation as some nests were built in other species of vines and shrubs and a few were constructed on the ground. Goodpaster and Hoffmeister (1954) suggested that availability of suitable avenues of escape by climbing might be an important factor in the selection of a nest site; but during this study, this factor did not seem of importance as mice jumped to the ground as frequently as they escaped by climbing when nests were disturbed. Packard and Garner (1964) also noted a mouse jumping to the ground from a disturbed nest.

The importance of these plants in golden mouse habitat has been noted in other studies. Barbour (1951) noted that greenbrier was always one of the dominant plants, whereas Goodpaster and Hoffmeister (1954) concluded that honeysuckle was the preferred vine at any elevation with greenbrier and certain other shrubs also being of importance. Handley (1948) found the golden mouse wholly confined to honeysuckle thickets when found on mountains. Occasionally they were recorded in greenbrier and blackberry, while at lower elevations, cane was used extensively. Ivey (1949) mentioned Spanish moss and greenbrier as important plants. In contrast to the above findings, Redman

and Sealander (1958) found this mouse inhabiting a pine-oak forest with little understory.

Hill and lowland forests. — The somewhat xeric hill forests in southern Illinois generally support sparse underbrush. On higher hills, honeysuckle was the only plant noted which provided suitable habitat, but this vine was seemingly restricted in distribution in these areas. The majority of forests at the Union County Refuge are of a swampy nature, and as such, do not support golden mice due to the absence of the three important understory plants which are found primarily in mesic forests. The golden mouse has been noted to prefer lowland areas to upland areas (Goodpaster and Hoffmeister, 1954; Barbour, 1942); however, it has been reported from an altitude of 4120 feet in North Carolina (Odum, 1949).

Disturbances. — In most areas where golden mice were noted, disturbances from lumbering and road construction had occurred. In certain areas, such activities permitted the invasion and establishment of the important understory species, particularly honeysuckle. Although exact times were unknown, disturbances probably occurred at least 15 years prior to this study.

Most of the forests at the Refuge are undergoing succession resulting from ex-

TABLE 1. Species and Occurrence of Trees over 3.5 Inches in d.b.h. Noted in 14 0.1-acre Quadrats.

Species	Representation in quadrats	Frequency index
Slippery elm (*Ulmus rubra*)	8	57.1
White mulberry (*Morus alba*)	8	57.1
Sweet gum (*Liquidambar styraciflua*)	7	50.0
Box elder (*Acer nugundo*)	6	42.9
American elm (*Ulmus americana*)	6	42.9
Persimmon (*Diospyros virginiana*)	5	35.7
Bitternut hickory (*Carya cordiformis*)	5	35.7
Southern hackberry (*Celtis laevigata*)	4	28.6
Chinquapin oak (*Quercus muhlenbergii*)	4	28.6
Black walnut (*Juglans nigra*)	4	28.6
Green ash (*Fraxinus lanceolata*)	3	21.4
Red oak (*Quercus rubra*)	3	21.4
Wild black cherry (*Prunus serotina*)	3	21.4
Redbud (*Cercis canadensis*)	3	21.4
Cottonwood (*Populus deltoides*)	3	21.4
White oak (*Quercus alba*)	3	21.4
Honey locust (*Gleditsia triacanthos*)	2	14.3
Sycamore (*Platanus occidentalis*)	2	14.3
Pignut hickory (*Carya glabra*)	2	14.3
Shagbark hickory (*Carya ovata*)	2	14.3
Pecan (*Carya illinoensis*)	2	14.3
Red mulberry (*Morus rubra*)	2	14.3
Pin oak (*Quercus palustris*)	1	7.1
Sassafras (*Sassafras albidum*)	1	7.1
Pawpaw (*Asimina triloba*)	1	7.1
Kentucky coffee tree (*Gymnocladus dioicus*)	1	7.1
Red maple (*Acer rubrum*)	1	7.1
Blue beech (*Carpinus caroliniana*)	1	7.1
Red haw (*Crataegus mollis*)	1	7.1
Silver maple (*Acer saccharinum*)	1	7.1
Black willow (*Salix nigra*)	1	7.1
Tulip tree (*Liriodendron tulipifera*)	1	7.1
Black locust (*Robinia pseudoacacia*)	1	7.1
Shellbark hickory (*Carya laciniosa*)	1	7.1
American ash (*Fraxinus americana*)	1	7.1
Hard Maple (*Acer saccharum*)	1	7.1

tensive timber harvest prior to 1947 when the State of Illinois purchased this tract. It is thought that as succession from cut-over areas to mature mesic forests proceeds, the golden mouse progressively loses portions of suitable habitat as tall trees tend to deter profuse growth of important shrubs and vines. This seems to have occurred at the Refuge where there are now only a few acres of optimal habitat. McCarley (1958) concluded that lumbering may benefit the golden mouse as this practice tends to open the canopy and permit lush growth of the understory. However, it was indicated that a dense canopy may be formed again in less than 30 to 40 years.

Distribution in Illinois. — The dissimilarity of vegetation occurring in southern Illinois and that of other regions of the State must be understood when the distribution of the golden mouse is considered. The three plants which seem to be required in the habitat of this animal are greatly or wholly restricted to southern Illinois. Cane is found only in the extreme southern region; Japanese honeysuckle is restricted primarily to the south; and all seven species of cat-brier recorded for the State are found in southern Illinois with four restricted primarily to this area (Winterringer and Evers, 1960).

Average annual precipitation is higher and temperatures generally warmer in southern Illinois than in other regions of the State. Such climatological factors determine plant communities present in these areas. The eastern deciduous forest occurs in most of southern Illinois. Much of central Illinois and part of the northern region is an ecotone between forest and prairie with the forests being restricted mainly to floodplains and dry areas in which the oak-hickory type supports less well developed understory than forests in which golden mice are found.

Nests

Nests were globular in form, usually hollow, and composed of an inner lining and an outer covering. The lining usually made up the bulk; finely shredded parts of sedges, grasses, or bark were commonly used in constructing this section, while bits of cloth, bird feathers, or "cotton" from cottonwood trees, *Populus* spp., were used less frequently. The covering was composed of whole leaves of trees, sedges, grasses, or coarsely shredded stem materials. Leaves identified were those of cat-brier, cane, box elder, *Acer negundo*, grass, sedge, elm (*Ulmus* spp.), honeysuckle, red haw, *Crataegus mollis*, maple, *Acer* spp., hackberry, *Celtis* spp., pin oak, *Quercus palustris*, grape, ash, *Fraxinus* spp., and spice bush. Silver maple samaras and stem materials from grape and honeysuckle were also noted in the covering. In regard to nest measurements, diameters ranged from 4.0 to 8.5 inches with the average being 5.8 inches. The height above ground varied from 8 inches to 20 feet 10 inches with an average measurement of 7 feet 2 inches (excluding ground nests). Packard and Garner (1964) found nests at heights of 1.5 to 25 feet in eastern Texas.

The average distance between nests was 43 feet. In two instances, an inhabited nest was found in close proximity of another occupied structure within the same day; a distance of 140 feet separated one pair and 180 feet the other. Eight solitary nests were found; all were noted in widely separated regions except two which were approximately 200 yards apart. As the immediate vicinity around each solitary nest was examined cursorily, intensive searches might have revealed additional nests.

Sites. — Arboreal nests were sometimes constructed in shrubs or forks of trees. In one instance, a cluster of thorns on the trunk of a honey locust, *Gleditsia triacanthos*, was utilized; but in most cases (55.6 percent), nests were supported entirely or partially by cane, honeysuckle, cat-brier, or grape. Most of the remaining nests were found near one or more of the four plants.

Of 87 nests located, 6 were found at ground level. Four of the ground nests were constructed at the bases of spice bush clumps; one was noted under a log, and one was situated on several shoots of cane about 1 inch above ground level. Other than location, ground nests were similar in all respects to arboreal nests. Most studies of the golden mouse describe use of arboreal nests with only a few reporting nests at ground level (Cory, 1912; Barbour, 1942; Eads and Brown, 1953).

Occupancy. — During the year, two inhabited nests were recorded on Plot 1 during July and November while one was noted in June, August, September, and October. Two occupied nests were recorded in other areas in April and one

in June, July, and August. A nest on Plot 1 contained a female with subadults in November, while two nests in a honeysuckle thicket outside the Refuge each yielded a female with suckling young on April 6. Layne (1958) also listed an occupied nest in December in southern Illinois. Packard and Garner (1964) recorded two inhabited nests in December and one in March in eastern Texas. Goodpaster and Hoffmeister (1954) found occupied nests from January through April and in November in Kentucky. From these studies, it is apparent that golden mice are capable of occupying arboreal nests at all times of the year.

In one instance a mouse was found to take over a nest after it was deserted; an individual of unknown sex was routed from a nest in June which had previously contained a litter of young and a female that were taken into captivity in April. Of the ten inhabited nests which contained only adults, a single individual was found except in one instance when two were observed. This is in contrast to the findings of Goodpaster and Hoffmeister (1954) and Barbour (1942) who commonly found several adults per nest. Of three inhabited nests found by Packard and Garner (1964), two contained single adults and the other a female with suckling young. Layne (1958) reported a nest containing two adults. During this study, mice were sensitive to disturbances of nests and would usually permanently desert a nest once caused to leave. On one occasion, several subadults were found in a nest from which they had been routed several days before.

Nesting Habits

The nesting habits of *O. n. aureolus* seemed to lack a definite pattern. Forty-one nests were found on Plot 1 during the first 9 months of study; new nests were lacking the last 4 months. The last inhabited nest was noted in November and the last newly constructed nest was recorded in March, yet mice were captured throughout the study including the winter period when arboreal nests were relatively easy to locate. A lack of new nests during the spring and summer was also noted on all other live-trapped areas; only one new nest was located on the Refuge during April through July. On three trapped areas, nests were never found to be inhabited. A majority of those nests found outside the Refuge were in ill-repair when found, and few were occupied.

The apparent lack of a pattern in nesting habits on trapped areas could have been due to increased utilization of less conspicuous nests such as those on the ground or in hollow trunks of trees due to disturbance of arboreal structures by the investigator. There was no evidence to suggest a greater degree of use of ground nests at a particular period of the year; however, this possibility existed.

Food

Seeds of poison ivy, blackberry, and bedstraw and small acorns were principal food items identified in 48 nests examined (Table 2). Cat-brier was conspicuously absent from food items identified, although it was present in many areas where nests were collected. These limited data suggest that the three plants most important in golden mouse habitat were unimportant in food habits. Goodpaster and Hoffmeister (1954), in a study of the golden mouse in Kentucky, listed greenbrier, sumac, wild cherry, and dogwood as main food items. Unopened seeds were sometimes found in nests. These may have represented a cache for future consumption, but the small quantity indicated that these were inedible or that they were left when nests were deserted. Food storage was indicated in one instance where five, entire, small acorns were found in a nest collected during November.

Goodpaster and Hoffmeister (1954) described two types of nests; these were the home and the feeding platform. The platform was used for feeding; as a result, the lining contained many seed hulls. The home, used as a residence by one or more animals, was usually devoid of food remains. During this study, most nests contained a few hulls. However, two nests were found which contained 2000 and 100 seed hulls. These nests could be termed feeding platforms, but most nests did not fit conveniently into either category as described by the above authors. Packard and Garner (1964) failed to find feeding platforms among 11 nests examined.

Home Range and Movements

The method used to calculate home ranges of mice captured on Plot 1 was the inclusive boundary method described

by Stickel (1954); ranges of animals captured on the edges of the grid were not included. The average home range of 1.2 acres obtained during this study (Table 3) was similar to that reported by McCarley (1958) who listed the average home range for a number of individuals captured 10 or more times as near 1.3 acres. Redman and Sealander (1958) calculated the average range of five individuals, apparently captured less than 10 times, as 0.13 acre. Dunaway (1955) reported the average range of three females, each captured 15 or more times each, as 0.26 acre.

Distances traveled by trapped golden mice were relatively small even over an extended period of time. On Plot 1, the greatest linear distance traveled by an individual during one day was 297 feet, while the greatest distance covered over an extended period of time was 483 feet (Table 4). The average distance traveled by nine individuals captured three or more times on Plot 1 was 240 feet.

The golden mouse seemed restricted to mesic wooded habitats. On Plot 1, eight traps were permanently set a few feet from wheat fields. Three individuals, including an adult and two subadults, were captured once in these traps. Eleven traps were set in lowland woodlots that bordered Plot 1. On only one occasion was an animal captured;

TABLE 2. Food Items Contained in 31 of 48 Golden Mouse Nests.

Food items	Representation in nests	Frequency index
Oak (*Quercus* sp.)	9	18.8
Poison ivy (*Rhus radicans*)	7	14.6
Bedstraw (*Galium* spp.)	5	10.4
Blackberry (*Rubus* spp.)	5	10.4
Grape (*Vitis* spp.)	4	8.3
Sassafras (*Sassafras albidum*)	3	6.3
Polygonum (*Polygonum scandens*)	3	6.3
Pokeberry (*Phytolacca americana*)	2	4.2
Hackberry (*Celtis* sp.)	1	2.1
Dogwood (*Cornus* sp.)	1	2.1
Black locust (*Robinia pseudoacacia*)	1	2.1
Holly (*Ilex* sp.)	1	2.1
Pawpaw (*Asimina triloba*)	1	2.1
Unidentified	12	25.0

TABLE 3. Home Range Size of Five Adu't Golden Mice.

Sex	Number of captures by months						Total captures	Home range in acres
	Aug.	Sept.	Nov.	Dec.	Feb.	Mar.		
Female	.....	1	1	1	1	11	15	1.5
Male	.....	.....	.....	1	.....	9	10	0.6
Female	.....	5	.....	.....	.....	.....	5	0.5
Male	.....	.....	.....	.....	1	5	6	1.9
Male	.....	.....	.....	.....	.....	5	5	1.6

it was taken 20 feet from a mesic forested habitat. This apparent avoidance of open fields and low woodlots indicated a limited pattern of movement. Komarek (1939) found that the golden mouse ranged least of several species of small mammals studied and indicated that populations of the former tended to be sedentary. As Plot 1 was an island of golden mouse habitat surrounded by cultivated fields and connected to other woodlots by two narrow strips of lowland forests, the population in this area was essentially isolated.

Population Densities

The greatest concentration of *O. n. aureolus* was noted on Plot 5 during the period January through March when

Table 4. Greatest Linear Distances Traveled by Nine Golden Mice.

Sex	Age	Number of captures	Period of movement	Distance in feet
Male	adult	5	March	483
	adult	5	August to December	413
	adult	6	March	297 (1 day)
	subadult	4	August	198
	adult	10	March	139
Female	adult	15	March	264
	subadult	3	August	198
	adult	4	August	94
	adult	3	March	78

Table 5. Comparison of Greatest Population Densities of Golden Mice per Acre on Five Areas.

Plot number	Size in acres	Months	Individuals captured	Density
1	7.5[1]	March, August	6	0.8
2	0.8	December	2	1.3
3	1.5	January, April	1	0.7
4	0.5	April	1	2.0
5	0.2	January	6	30.0

[1] Suitable golden mouse habitat constituted approximately 5 acres.

ten individuals were captured. As determined from trapping, a population density of 30 mice per acre was present during January (Table 5). It is of interest to note that only 17 individuals were taken on the larger Plot 1 during the year. The greatest monthly density occurred on Plot 1 during March and August when six animals were captured; this represented a density of 0.8 mice per acre. During the year, only single captures of individuals were noted on Plot 2 (4), Plot 3 (2), and Plot 4 (1). The densities on plots 2 through 4 approximated that on Plot 1. On all plots, there were months of intensive trapping when no mice were taken. McCarley (1958) reported densities of 2.2 to 0.0 mice per acre in eastern Texas, while Shadowen (1963) recorded densities of from 2.79 to 0.08 mice per acre in Louisiana.

Acknowledgments

The work reported in this paper is part of that submitted in a thesis to the Graduate School of Southern Illinois University for partial fulfillment of the requirements of the M.A. degree in zoology. This paper is an outgrowth of Project No. 45, Small Mammal Studies, of the Cooperative Wildlife Research Laboratory. Field work was performed under a fellowship granted by the National Science Foundation. My sincere gratitude is extended to my major advisor, Dr. W. D. Klimstra, Director, Cooperative Wildlife Research Laboratory, for criticisms of the manuscript and for invaluable suggestions concerning field work. Appreciation is expressed to Dr. Robert Mohlenbrock, Associate Professor of Botany, for identification of plants and to the Illinois Department of Conservation for use of the clubhouse at the Refuge for living quarters. A debt of gratitude is owed several former students of the Cooperative Wildlife Research Laboratory who aided this study in many ways.

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Manuscript received June 15, 1966.

MITOCHONDRIAL RESPIRATION IN MAMMALIAN LIVER DURING COLD EXPOSURE AND HIBERNATION

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ABSTRACT. — Studies were made of the effect of cold exposure and hibernation (1-3 months at 5°C) on succinate respiration of liver mitochondria in hamsters and chipmunks. Measurements which were made included: 1) mitochondrial respiration with excess exogenous substrate, 2) mitochondrial respiration with excess exogenous substrate plus ADP, 3) respiratory stimulation caused by ADP addition, and 4) efficiency of oxidative phosphorylation. Succinate-ADP respiration was increased in mitochondria from hibernating chipmunks and decreased (both with and without added ADP) in hibernating hamsters. Respiration and phosphorylation were unaffected in chipmunks which did not hibernate during cold exposure but succinate respiration was decreased and the P:O ratio increased in nonhibernating cold-exposed hamsters.

The purpose of this investigation was to study the effect of cold exposure and hibernation on oxidative activity of liver mitochondria isolated from various species of hibernators. A wealth of data has accumulated over the years on natural mammalian hibernation (Lyman and Chatfield, 1955) and these studies have demonstrated that the phenomenon of hibernation is not precisely the same among all mammals and differs even among various families of rodents (Lyman, 1954). Relatively few studies have been carried out, however, investigating possible differences between hibernators at the cellular and enzymatic level. As a result, our knowledge of the cellular changes effected by hibernation is limited. The greatly decreased general metabolism observed in dormant animals, however, makes the cellular metabolic events which occur during hibernation of special interest.

A limited number of studies have been carried out measuring the oxygen consumption of various tissues of hibernators, such as the liver, muscle, kidney, brain, and brown fat. Some of these studies have reported a slight reduction in the oxygen consumption of brain and kidney slices in the hibernating hamster and the hibernating ground squirrel (Hook and Barron, 1941; Kayser, 1954; South, 1958; and Meyer, 1959). Meyer also reported, however, that the respiratory activity of cardiac and skeletal muscle tissue increases by 60-120% during hibernation in the ground squirrel. Chaffee et al. (1966) stated that liver mitochondria from hibernating ground squirrels were 50% higher in the oxidation of succinate than were control mitochondria.

In many of these studies, it has been noted that certain hibernators, particularly the hamster, show an in-

constancy when entering hibernation while they are exposed to cold in the laboratory (Pohl, 1965) such that some of the animals may never hibernate. Comparisons of cellular metabolism between hibernating animals and cold-exposed animals which have failed to hibernate have been made by measuring oxidative activity of the tissues of both groups of animals. Denyes and Hasset (1960) observed that in the golden hamster the respiration of liver slices actually increases after cold exposure or hibernation. Similarly, increased succinic oxidase activity of liver mitochondria was found in both cold-exposed and hibernating hamsters at 37°C (Chaffee, 1957; Chaffee et al., 1961). Inasmuch as a similar increase occurred in both hibernating and cold-exposed hamsters which did not become dormant (Chaffee, 1957), Chaffee stated that the increased metabolic capacity reflects a response to cold exposure and is not a result of hibernation itself. A study by Mokrasch et al. (1960), however, failed to confirm this view; they reported no significant alteration from the control level in the rate of oxygen consumption by liver mitochondria of hibernating hamsters.

The present study was undertaken, therefore, to learn more about the cellular metabolic changes which take place during hibernation by studying liver mitochondral activity in animals exposed to cold. The specific objectives were: 1) to compare the effects of cold exposure in two species of hibernators, *Mesocricetus auratus*, the golden hamster, and *Tamias striatus*, the eastern chipmunk, to see if any differences in cellular activity during hibernation are apparent in these two species, and 2) to compare the results obtained on hibernating animals with those obtained on animals, also exposed to cold, but which fail to hibernate.

Materials and Methods

Eastern chipmunks were trapped on the campus of The Pennsylvania State University. Eighteen of these chipmunks, both males and females, were exposed to 5°C for 1-3 months. Six of the chipmunks entered hibernation while 6 others died during exposure to cold. The remaining 6 chipmunks exposed to cold remained active and showed no signs of becoming torpid. These cold-exposed active and hibernating chipmunks (plus 6 controls maintained at an ambient temperature of 24° ± 1°C) were used to study the effect of cold on liver mitochondrial respiration.

In addition, twenty adult male hamsters, (purchased from the Con Olson Company, Madison, Wisconsin) were exposed to the same cold temperature for 1-3 months and ten others were maintained at ambient temperature. Six of the cold-exposed animals hibernated while 3 died during exposure. The remaining cold-exposed animals remained active. The effect of cold on liver mitochondrial oxidative metabolism was then studied on 6 cold-exposed, 6 hibernating, and 6 control hamsters. All animals (both chipmunks and hamsters) were fed Purina Laboratory Chow and water *ad libitum*.

The entire procedure for the isolation of the mitochondria was carried out in a cold room (1 to 2°C). Animals were killed with a sharp blow on the head, and the liver was quickly removed and placed into an ice-cold isolation medium. The isolation medium contained 225 mM mannitol, 75 mM sucrose, and 0.1 mM EDTA. Homogenization of the tissue was carried out by forcing a rotating Teflon pestle to the bottom of the grinding tube. Washed mitochondria were then prepared by differential centrifugation in a refrigerated centrifuge according to the method described by Schneider (1948). The nitrogen content of the mitochondrial preparation was determined by the micro-Kjeldahl method described by Ma and Zuazaga (1942).

Measurements of respiration and phosphorylation were made polarographically

at 25°C using the rotating oxygen electrode as originally described by Chance and Williams (1955) and the Oxygen Monitor System manufactured by Yellow Springs Instrument Company. The reaction medium used has been described elsewhere (Frehn and Anthony, 1965). Mitochondrial substrate respiration was measured by adding 0.15 ml of the mitochondrial suspension to 3.0 ml of the reaction medium containing substrate. After measuring mitochondrial respiration on exogenous substrate for approximately 3-4 minutes, 0.01 ml of 0.05 M ADP was added to the reaction mixture in order to measure the substrate-ADP respiration rate.

Results and Conclusions

Table 1 summarizes the results obtained on the mitochondria of control, cold-exposed, and hibernating chipmunks. Two types of measurements were made. These were: 1) the efficiency of oxidative phosphorylation as reflected by the P:O ratios; and 2) exogenous substrate (succinate) and exogenous substrate-ADP rates of respiration. Respiration values represent X±S.E. in μM O_2/sec/mg of nitrogen. The R_s value represents the respiratory stimulation caused by the addition of ADP. It is evident from these data that the P:O ratios remain unaltered in washed mitochondria in cold-exposed and hibernating chipmunks. Likewise, succinate respiration is unaffected in mitochondria from both groups. The R_s values shown in Table 1, however, indicate that ADP stimulated substrate respiration more in hibernating animals than in either control or cold exposed chipmunks. Further examination of the data indicates that this elevated R_s value is due to a significantly increased substrate-ADP rate of respiration in mitochondria from hibernating chipmunks.

The respiration rates and P:O ratios obtained on hamster liver mitochondria are found in Table 2. As in the results obtained on hibernating chipmunks, these data show that the P:O ratio remains unchanged from the control level in hibernating hamsters. In contrast to hibernating chipmunks, however, respiration rates are significantly reduced in mitochondria from hibernating hamsters. Succinate respiration is reduced by 33% and succinate-ADP respiration is reduced by 26%. The R_s value is the same, however, for the hibernators as for the controls. Also in contrast to the chipmunks, the results in Table 2 show that the

Table 1. Effect of Cold (1-3 months at 5°C) and Hibernation on Exogenous Substrate Respiration and Phosphorylation in Chipmunk Liver Mitochondria.

Chipmunks	N	Succinate	Succinate plus ADP	R_s	P:O
Control	6	0.77 ± .04	4.94 ± .29	6.4 ± .2	1.60 ± .05
Hibernating	6	0.83 ± .05	6.52 ± .43[1]	7.9 ± .3[2]	1.57 ± .02
Cold-exposed	6	0.81 ± .07	5.07 ± .45	6.3 ± .4	1.63 ± .04

[1] $P < .02$
[2] $P < .01$

greatest response to ADP addition occurred in mitochondria from hamsters which failed to hibernate. Examination of these data indicates that the elevated R_s value observed in cold-exposed hamsters is due to a lowered rate of substrate respiration and is not due to an elevated substrate-ADP rate of respiration.

Thus, there appears to be rather significant differences at the cellular level between hibernating chipmunks and hibernating hamsters. The most obvious difference is in mitochondrial succinate-ADP respiration. In substrate-ADP respiration, substrate and ADP are present in excess. Therefore, the main rate-limiting factor of respiration is the concentration of functional respiratory units present in the mitochondria. Thus, the elevated R_s value observed in hibernating chipmunks apparently reflects an increased concentration of functional respiratory units in liver tissue of hibernating chipmunks. In contrast, the reduced respiratory rates observed in mitochondria from hibernating hamsters indicates a decreased concentration of functional respiratory units in the liver tissue of these animals.

Although succinate-ADP respiration remains unaltered, there does appear to be significant differences in mitochondrial activity between hamsters and chipmunks which were exposed to cold but which failed to hibernate. Succinate respiration, unaltered in cold-exposed chipmunks, is slightly reduced in cold-exposed hamsters. Substrate rate of respiration may be influenced either by the availability of endogenous ADP or by the concentration of functional respiratory units. Since the concentration of functional respiratory units appears to be unchanged during cold exposure, it would appear that there is a lower availability of endogenous ADP in mitochondria of cold-exposed hamsters. This might occur in mitochondria in which phosphorylation and respiration become more tightly coupled. This conclusion is substantiated by the elevated P:O ratio found in mitochondria from cold-exposed hamsters (see Table 2).

Thus, differences in cellular metabolic activity were noted between hamsters and chipmunks in both the cold-exposed and hibernating groups. These results suggest, therefore, that

TABLE 2. Effect of Cold (1-3 months at 5°C) and Hibernation on Exogenous Substrate Respiration and Phosphorylation in Hamster Liver Mitochondria.

Hamsters	N	Succinate	Succinate plus ADP	R_s	P:O
Control	6	0.54 ± 0.02	2.17 ± 0.13	4.0 ± .1	1.34 ± 0.03
Hibernating	6	0.36 ± 0.02[1]	1.51 ± 0.03[1]	4.3 ± .2	1.40 ± 0.03
Cold-exposed	6	0.47 ± 0.02[2]	2.18 ± 0.06	4.7 ± .1[1]	1.46 ± 0.03[3]

[1] $P < .001$
[2] $P < .05$
[3] $P < .02$

differences between hibernators do exist at the cellular and enzymatic level. Inasmuch as mitochondria from cold-exposed animals showed a different respiratory activity than mitochondria from hibernating animals, the results do not appear to agree with earlier reports (Chaffee, 1957) that the altered metabolic capacity observed in hibernating animals merely reflects a response to cold exposure and is not a result of hibernation, itself. It should be noted, however, that the study by Chaffee was carried out at 37°C whereas in the present study, mitochondrial activity was measured at 25°C. Thus, it would appear desirable that additional studies be performed at various temperatures.

Acknowledgments

This research was supported in part by Research Grants G. M. 7678-03 and G. M. 13358-01 from the National Institutes of Health and by a Research Grant from the Illinois State Academy of Sciences for the year 1965-66. I wish to thank Mr. Byron Bertagnolli for his invaluable technical assistance during the course of this study.

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Manuscript received June 30, 1966.

AN OCCURRENCE OF *HEXAGONARIA* IN THE GRAND TOWER FORMATION OF SOUTHERN ILLINOIS AND SOUTHEASTERN MISSOURI

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ABSTRACT. — A new species of colonial coral, *Hexagonaria mesocincta*, is described. Its occurrence in the lower part of the Grand Tower Formation (Middle Devonian) in Ste. Genevieve County, Missouri, and in the basal Grand Tower Limestone in Union County, Illinois, suggests a direct correlation of these beds.

In 1910 T. E. Savage reported the occurrence of a Devonian colonial coral, *Hexagonaria*, from the uppermost bed of the Grand Tower Formation in the Backbone at Grand Tower, Illinois, as *Cyathophyllum rugosum* Rominger. Ten years later (1920) in an unpublished report of the Illinois Geological Survey, Savage listed this same species from the upper beds of the Grand Tower Formation on Green Creek (near the middle of the north side of Sec. 23, T.12S., R.2W., about two miles northwest of Jonesboro) in Union County, Illinois. These were the first reports of the occurrence of *Hexagonaria* in the Grand Tower Formation.

E. C. Stumm (1948) placed *Cyathophyllum rugosum* Rominger in synonymy with *Hexagonaria curta* Stumm. Specimens of *Hexagonaria* collected recently from the uppermost bed of the Grand Tower Formation in the Backbone are not conspecific with *H. curta*. No specimens of *Hexagonaria* were found in the upper beds of the Grand Tower Formation on Green Creek.

Hexagonaria mesocincta, new species

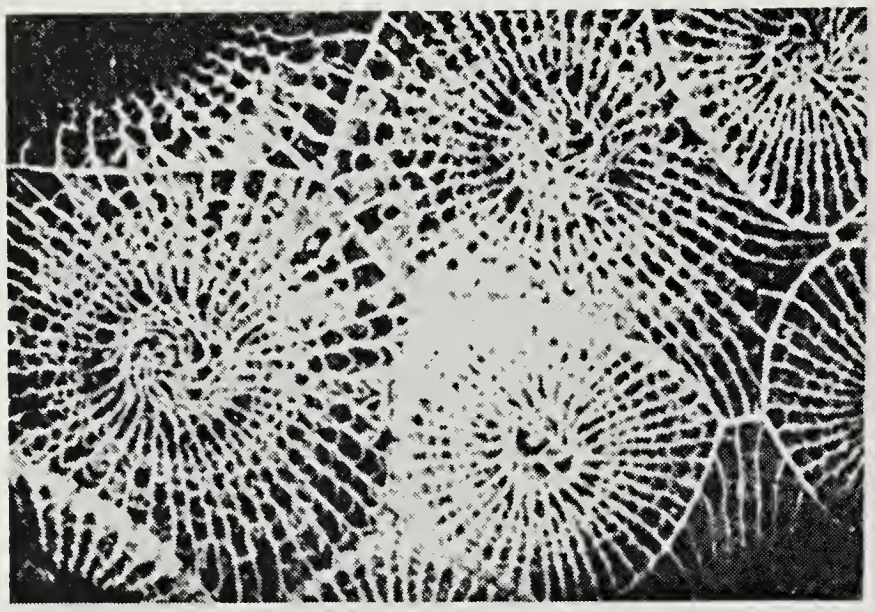
Holotype.—Southern Illinois University Museum No. 701, a large, weathered specimen collected from the Grand Tower Formation. (Fig. 3-4)

Occurrence.—Grand Tower Formation, along the north bank of Clear Creek in the NE¼ SE¼ SW¼ Sec. 27, T.11 S., R.2 W., Union County, Illinois (Southern Illinois University Museum No. 705).

Grand Tower Formation, just to the south of the west pit of the Ozora quarry in the limestone bed cut by the east edge of the pit (bed #7) in the SE¼ SE¼ Sec. 5, T.36 N., R.9 E., Ste. Genevieve County, Missouri (holotype). (Fig. 7).

Diagnosis.—The species *Hexagonaria mesocincta* can be distinguished from all other species of the genus *Hexagonaria* by means of the combination of axial whorls, thin coralite walls and number of septa.

Description of the holotype.—The coralla are cerioid, irregularly hemispherical in outline and composed of



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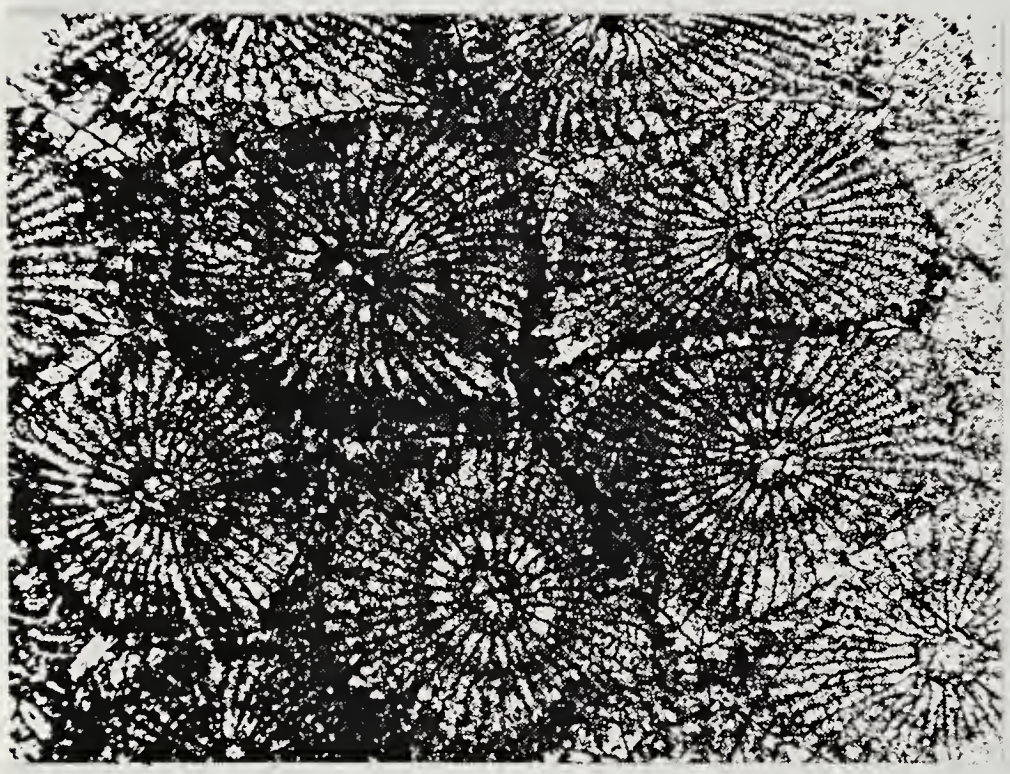

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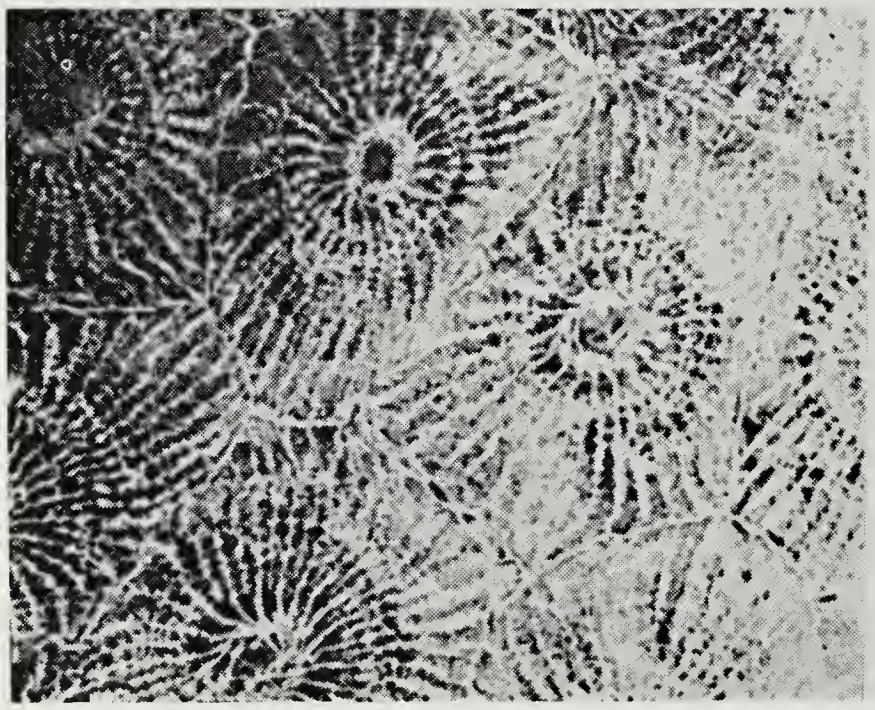

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corallites that are both pentagonal and hexagonal in outline, ranging from 10 mm. to 20 mm. in diameter. The polygonal walls are very thin and straight or curved. The calices are shallow with wide peripheral platforms, which slope toward the slightly elevated circular rims which surround the medial pits. The floors of the pits are occupied by the axial whorls produced by the ends of the major septa. These whorls may be

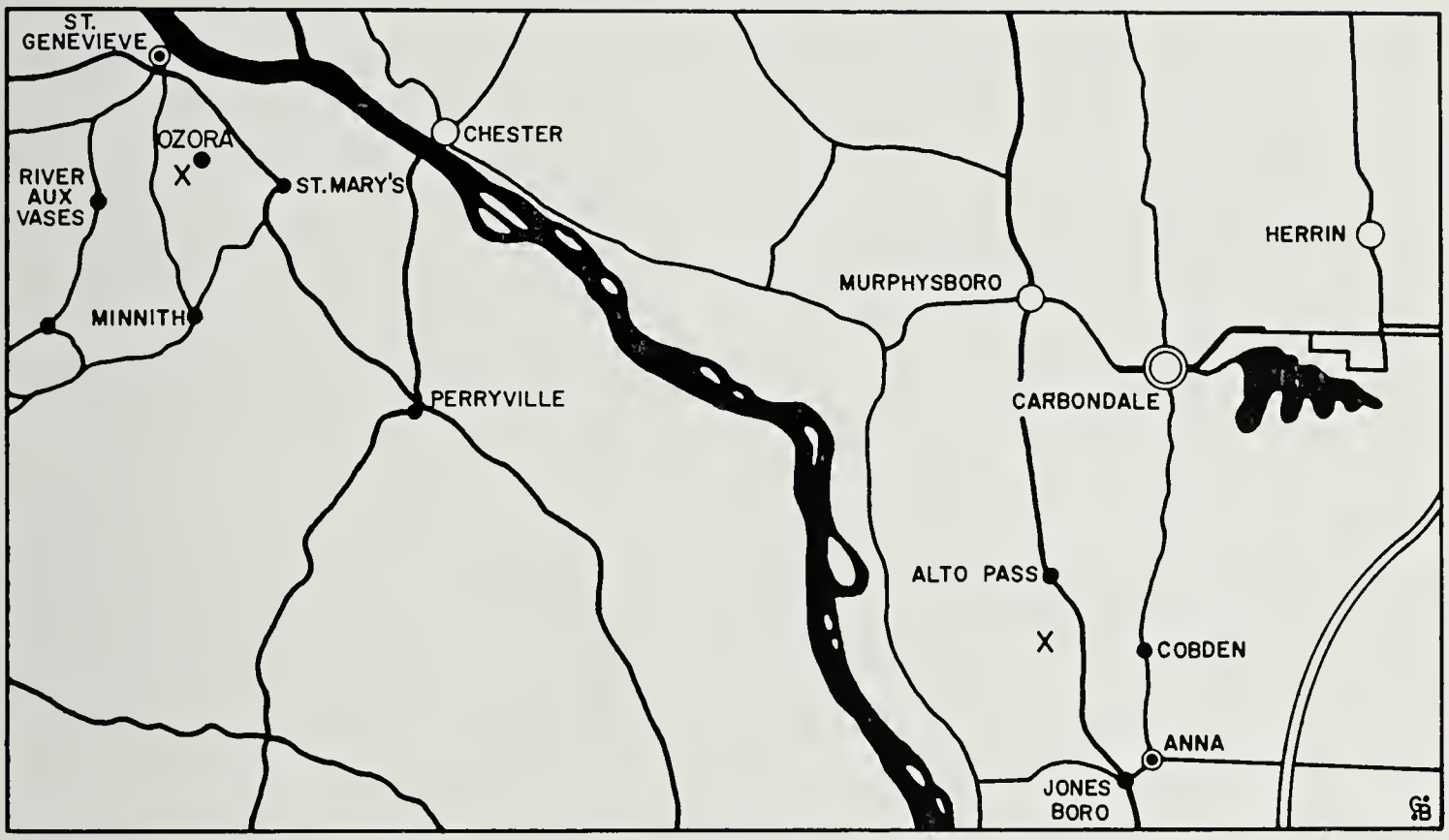

FIGURE 7.—Map showing the sites (X) where *Hexagonaria mesocincta* occurs; south of Alto Pass (along the north bank of Clear Creek in the NE¼ SE¼ SW¼ Sec. 27, T.11 S., R.2 W.), Union County, Illinois and southwest of Ozora (just south of the west pit of the Ozora quarry in the SE¼ SE¼ Sec. 5, T.36 N., R.9 E.), Ste. Genevieve County, Missouri. Map prepared by Cartographic Office, Mississippi Valley Investigation, 1966.

FIGURES 1-6.—*Hexagonaria cincta* (Stainbrook): 1. Transverse section showing the solid axial whorls and long, thin septa. Paratype (Stainbrook Collection—No. 1172). Jeffersonville Limestone, Jeffersonville, Indiana (after Stainbrook). 2. Longitudinal section showing incomplete tabulae anastomosed with axial ends of major septa: holotype (Stainbrook Collection—No. 1198) after Stainbrook). *Hexagonaria mesocincta*: new species: 3. Transverse section showing long, thin septa, yardarm carinae and axial whorls; holotype (Southern Illinois University Museum Collection—No. 701) from Grand Tower Limestone, Ozora quarry, Ste. Genevieve County, Missouri. 4. Longitudinal section showing closely-spaced carinae and incomplete tabulae anastomosed with axial ends of major septa; holotype. *Hexagonaria suncincta*: 5. Transverse section showing thin, well-spaced septa and axial whorls and septa with yardarm carinae; holotype (University of Michigan, Museum of Paleontology—No. 24233) from Bois Blanc Formation, one mile west of Mackinac City, Michigan (after Stumm). 6. Longitudinal section showing, complete, close-set, horizontal tabulae and carinae; paratype (University of Michigan, Museum of Paleontology—No. 24236). Horizon and locality same as that of the the holotype (after Stumm). All figures X2.

FIGURES 1, 2, 5 and 6 reproduced by permission of Lewis B. Kellum, Museum of Paleontology, University of Michigan.

elevated, forming circular axial bosses.

In transverse section the septa in the larger corallites range from 44 to 46 in number. The major septa extend into the tabularia, where they are deflected to form axial whorls, which occupy the central portion of the tabularia. The minor septa terminate at the margins of the tabularia. Both orders of septa are carinate across the dissepimentaria, with yardarm carinae occupying the central part of the septa and offset carinae occupying the irregular peripheral and axial ends of the septa. The septa are very irregular near the periphery.

In longitudinal section the tabularia average less than one-third the width of the corallite and contain a tangled series of tabellae, which are greatly anastomosed with the axial ends of the major septa. The dissepimentaria consist of small, distally convex dissepiments. Dissepimentaria are crossed by numerous distally arched carinae.

Comparisons.—This species resembles both *H. cincta* (Stainbrook) (Fig. 1-2) and *H. subcincta* Stumm. (Fig. 5-6). In *H. mesocincta* the walls are thin like in *H. subcincta*. In all other respects, *H. mesocincta* is similar to *H. cincta*.

Stuart Weller (1928) noted the occurrence of a zone of abundant corals in the lower part of the Grand Tower Formation in the Little Saline Creek area of Ste. Genevieve County, Missouri. At that time he stated: "the well known fossil coral reef at the Falls of the Ohio occurs in the lower portion of the Jeffersonville limestone of Indiana. The fossil coral reef in Ste. Genevieve County is far less extensive than that at the Falls of the Ohio, but the species are all common to the two regions, and there can be no hesitation in considering them to be contemporaneous in age". He also stated that this coral zone was not present in the Grand Tower Formation at Grand Tower, Illinois. However, none of the corals from the Grand Tower Formation in Missouri were figured or described.

Thus, since corals were the main basis for correlation used by Weller, no detailed correlations were established within the Grand Tower Formation between Missouri and Illinois.

The Devonian colonial coral *Hexagonaria mesocincta,* new species, is present in the coral zone reported by Weller (bed #7 about 40 feet above the base of the Grand Tower Formation in quarry hill, SE¼ Sec. 4, T.36 N., R.9 E., Ste. Genevieve County, Missouri). This species is similar to *Hexagonaria cincta* (Stainbrook), which occurs in the basal coral zone of the Jeffersonville Limestone in the Falls of the Ohio region. *Hexagonaria mesocincta* is also present in the abundantly coralliferous basal bed of the Grand Tower Limestone, immediately above the Dutch Creek Sandstone, on Clear Creek (along the north bank of Clear Creek in the NE¼ SE¼ SW¼ Sec. 27, T.11 S., R.2 W., about two and three quarter miles south of Alto Pass) in Union County, Illinois.

This situation seems to verify a suggestion made by J. M. Weller (1944) that the Grand Tower Formation is older in Missouri than it is in Illinois. At the same time, the presence of the same coral species

suggests a direct correlation of the middle lower part of the Grand Tower Formation in the Ozora quarry (quarry hill) of Ste. Genevieve County, Missouri, with the basal part of the Grand Tower Limestone on Clear Creek in Union County, Illinois.

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Manuscript received June 3, 1966.

THE MORPHOLOGY, MIGRATION AND PRESSURE DEVELOPMENT OF ORIENTED PLASMODIA OF THE SLIME MOLD

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ABSTRACT. — Starved plasmodia of the myxomycete, *Physarum polycephalum*, were unidirectionally oriented on nonnutrient agar and exhibited both a characteristic morphology and migration rate. The morphology described consists of five distinct areas: (1) the advancing front, (2) the flattened sheet area, (3) the tubule area, (4) the major tube area and (5) the residual flattened sheet area. Alteration of migrating plasmodia indicates that a unified advancing front behaves as the anterior end of a single organism and determines the polarity of a plasmodium. Analyses of migration rates of twenty plasmodia demonstrate that starving plasmodia migrate at approximately seven hour intervals which are separated by pauses. As the time of starvation is increased, the migration rate increases and the length of the pause period also increases. Pressure measurements indicate that only limited volumes of endoplasm are in the sol condition at any one time.

The endoplasm of myxomycetes streams to and fro in a regular periodic fashion termed shuttle flow. Associated with the alternating flow of protoplasm is the movement of the organism over a surface. The development of advancing areas and the movement of a plasmodium on a uniform substrate (such as agar) usually takes place in an apparently random fashion. Therefore, early investigations of movement, potentials, and the effects of external factors on myxomycetous plasmodia are made suspect by the failure of the investigator to define adequately the physiological state of the organism and to put the organism in such a condition that one could predict, with some certainty, its future behavior under the same conditions. The introduction of the double chamber technique (Kamiya, 1940) provided considerable impetus to research on slime mold plasmodia, since Kamiya had put the organism into an experimental situation which could be repeated.

The discovery by Anderson (1961) that the organism would not migrate any appreciable distance over parafilm led to his development of a method for orienting plasmodia. This technique is more advantageous than the double chamber method for the following reasons: (1) the organism is in a starved condition, migrating at a measurable rate, which constitutes a semidefined physiological state; (2) this state is readily reproduced; (3) the direction of migration can be controlled; (4) the future behavior of the organism can be predicted; and (5) a much larger organism is obtained; this lends itself to certain experiments.

Materials and Methods

The organism, *Physarum polycephalum*, was cultured in the dark on rolled oats using a modification of the method described by Camp (1936). A continuous succession of subcultures were maintained during the three year period of these experiments. The plasmodia were migrated on agar filled trays after the method described by Miller, Anderson and Peterjohn (1964).

Morphology

A unidirectionally oriented migrating plasmodium exhibits a characteristic morphology which can be designated as having five distinct areas (Fig. 1): (1) the advancing front area, (2) the secondary front or the flattened sheet area, (3) the tubule area, (4) the major tube or tubes, and (5) the residual flattened sheet area. Each of these areas is subject to change with changes in the ex-

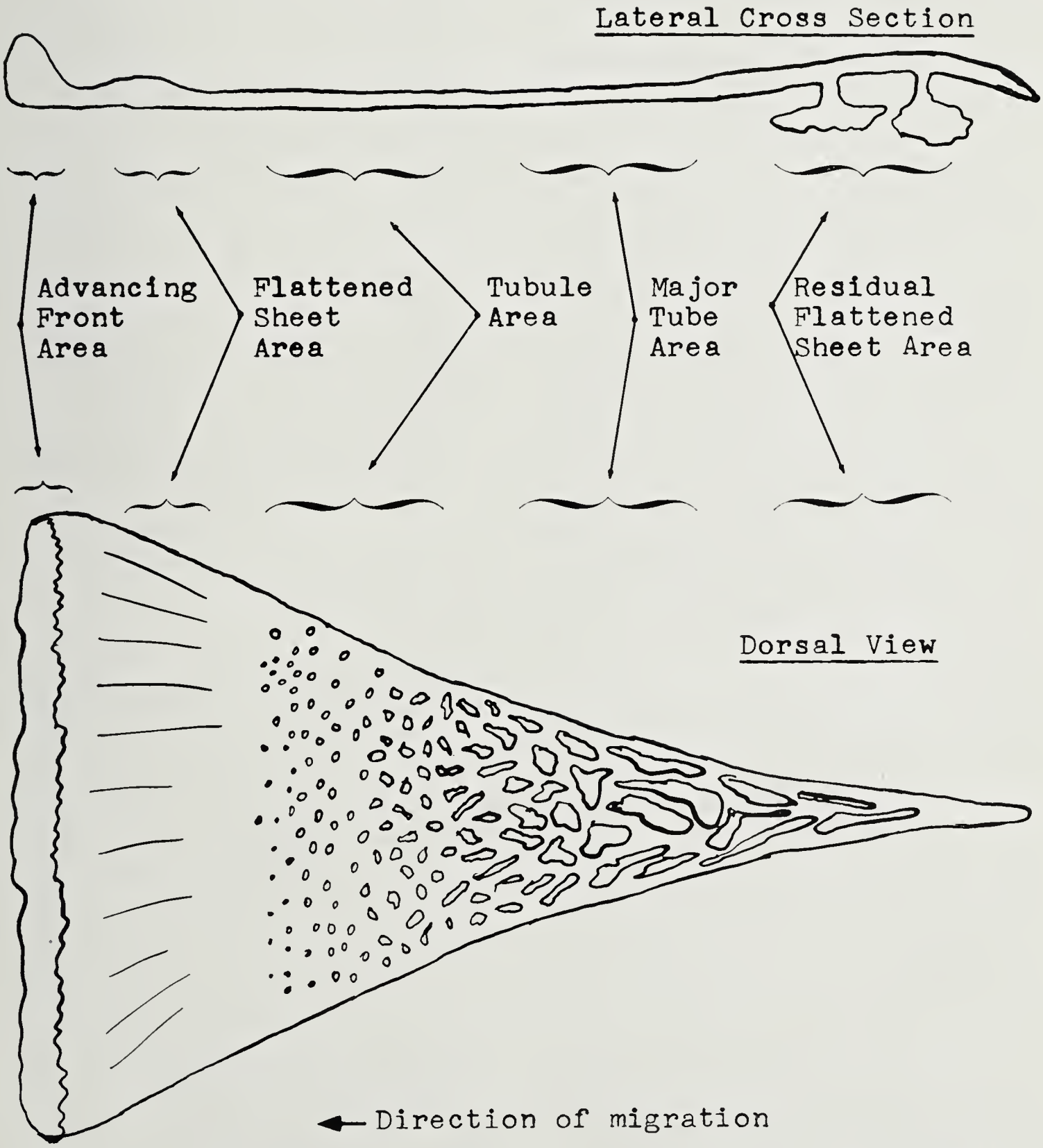

Figure 1.—Diagramatic Morphology of an Oriented Plasmodium. Illustrated are the Five Distinctive Morphological Areas Seen in a Unidirectionally Oriented Plasmodium.

ternal environment and time, but their general forms can be seen in the average oriented plasmodium.

Advancing Front Area. — The advancing front area is the part of the plasmodium which determines the direction of movement of the mass of the plasmodium. If viewed from above, this advancing front area is usually lobulated and thicker than the remainder of the frontal area. This lobular area is preceded by the hyaline layer of its foremost portion. If the advancing edge is viewed under a coverslip, the hyaline layer is then clearly seen. In non-oriented migrating plasmodia, this advancing area proceeds in one direction for a period of time, after which it is retracted, and a new advancing area develops in another part of the organism.

Flattened Sheet Area. — The area immediately behind the advancing front (i.e., the secondary front) is much flatter and usually has a shiny appearance. Under the microscope small tubules can be seen internally.

Tubule Area. — This is the part of the plasmodium where the tubes increase in size and become visible macroscopically. Unlike the tubules of the flattened sheet area, these are more permanent structurally and are not so readily changed. It is also in this area that the intertubular protoplasm begins to thin out. Thus, the flattened sheet area is transformed into a reticular area with residual flattened sheet areas in the reticulum. This in turn is transformed into a reticulated network of tubes with no protoplasm in between.

Major Tube Area. — The tubes finally coalesce near the rear into the major tube or tubes. A major tube is usually elevated above the substrate by smaller projecting tubules which lead laterally outward to residual flattened sheet areas. Lewis (1942) also noticed this condition in non-oriented plasmodia. The space between each projecting tubule and the substratum is usually filled with slime. In some plasmodia, the portions of the tubes between anchoring sites may curl into knots. The major tubes eventually trail off into slime tracks in the posterior.

Residual Flattened Sheet Area. — The part of the plasmodium interspersed between the reticular tubules is referred to as the residual flattened sheet area. It represents islands of protoplasm which have not yet completed the transformation to the tubule but are in some intermediate stage.

Migration

Horizontally Migrated Plasmodia. — Plasmodia were allowed to migrate horizontally on agar (2% in tap water), and the distance migrated was recorded as a function of time. A plot of time versus distance for three such experiments is shown in Figure 2. These figures indicate that the migration rate of a starving plasmodium is not constant but increases with time. In addition, pauses in migration were apparent. Analyses of twenty horizontally-oriented plasmodia show that the same pattern occurred in each one (that is, an increase of migration with time). On close inspection of migration rate plots and time lapse films, it was noted that migration was interrupted by pauses at regular intervals, but that the migration rate was approximately uniform during each of the seven to ten hour activity periods between pauses (Fig. 3). The longer a plasmodium migrated the longer became each succeeding pause. Guttes and Guttes (1963) demonstrated that in non-oriented plasmodia motility ceases when nuclear division occurs. Phase contrast microscopical observation of two different plasmodia during pause in migration showed division figures. Although each successive pause

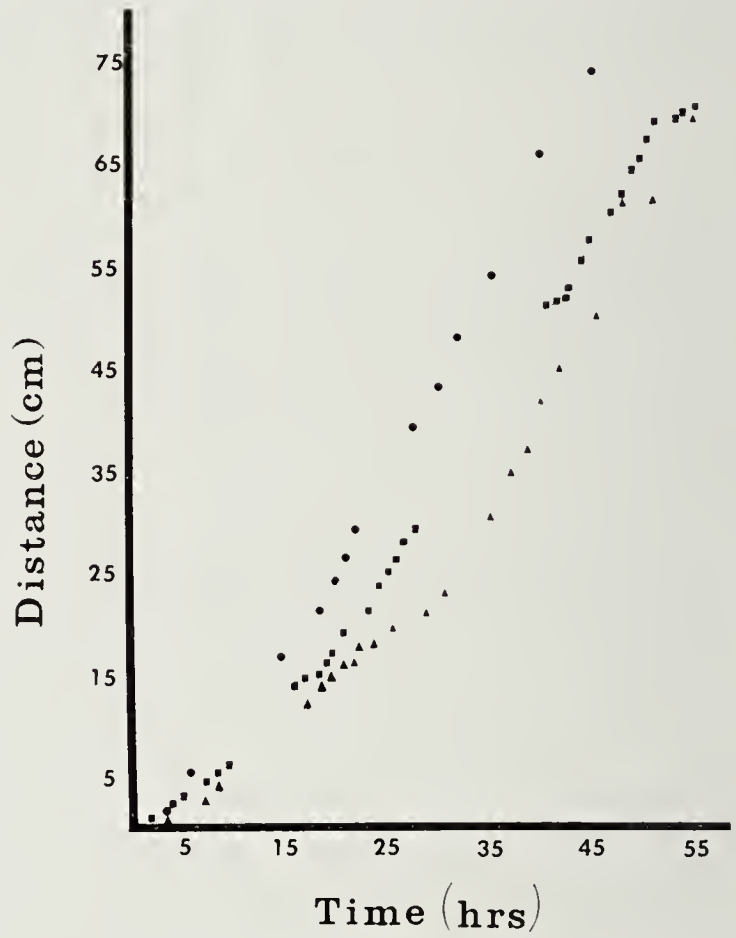

Figure 2. — Migration Rates of Three Oriented Plasmodia.

was of longer duration than the previous one, the periods of migration were of approximately the same length. However, the rate of migration increased after each successive pause. Plasmodia with the morphology and activity described above have been kept migrating on non-nutrient agar in the starved condition for over five days.

Relationship of Morphology to Migration. — Because oriented plasmodia display these different morphological regions, experiments were undertaken to remove or alter portions of these regions to determine their role in the motile phenomenon. If the advancing front were destroyed or removed, translocation over the substratum stopped until a new advancing front area developed. Interference with the advancing front area, such as mutilation, usually resulted in a change in polarity (i.e., direction of migration). In contrast to this, the removal of one third of the major tube area of a plasmodium did not affect its direction or rate of movement.

Vertically Migrated Plasmodia. — The shuttle flow of protoplasm does not vary its rate of flow or period even though the migration rate increases (Kamiya, 1959; Anderson, 1949). Kamiya indicated that the two largest factors determining the migration rate of a plasmodium were the net volume of protoplasm transported and the motive force developed. In terms of the measurements obtained from his double chamber, Kamiya reported a pressure difference of fifteen cm of water. Assuming that the endoplasm is a continuous sol from the anterior to the posterior end of a plasmodium, we thought it seemed likely that if a large plasmodium were forced to migrate vertically, then large hydrostatic pressures should develop in the lower (rear) tubes of the plasmodium. It was assumed that the maximum height a plasmodium could then migrate upwards would be approximately fifteen cm. This was predicated on the basis of the motive force measurements of Kamiya. Because we had found that the presence of nutrient material in an area prolonged the maintenance of tubes to that area, we supplied large vertically-oriented plasmodia with a very small amount of food (three oat grains or more) at the initial transplant site. Under these circumstances, the plasmodia migrated vertically in the same manner as horizontally except that there was not so pronounced an increase in the rate of movement and their tubes were maintained over extended distances.

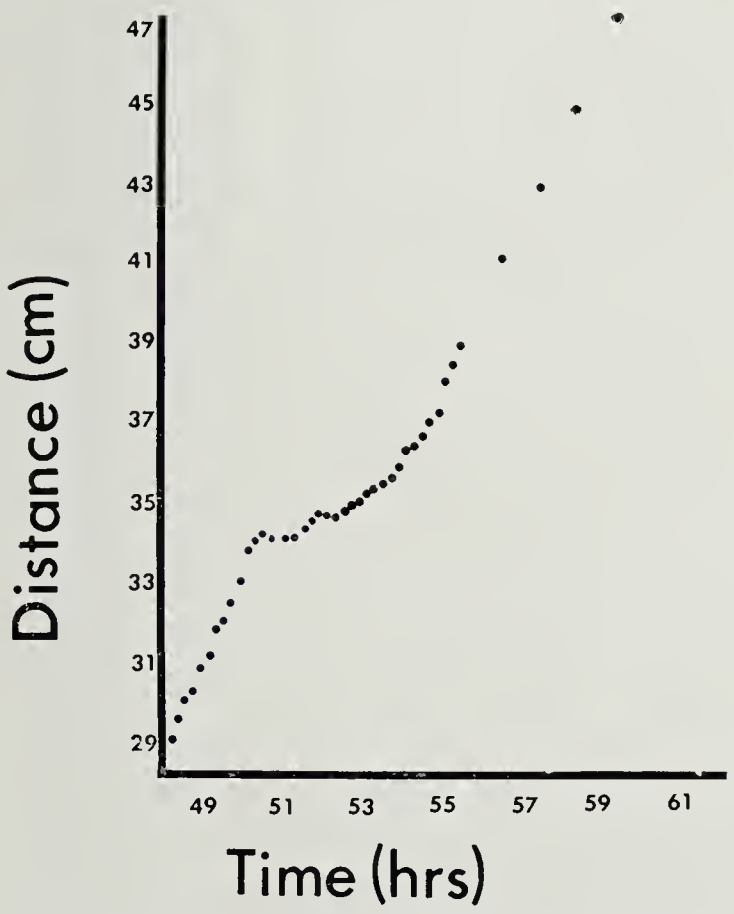

FIGURE 3. — Migration Rate During a Selected Interval for an Oriented Plasmodium to Show Period of Pause.

In one of eight experiments conducted with vertically-oriented plasmodia, a plasmodium migrated 66 cm up on an agar surface and was continuous from the bottom to the top. The migration rate of a vertically-oriented plasmodium followed the same general pattern as one which migrated horizontally. Since these results were not in agreement with what had been predicted on the basis of pressures determined by Kamiya's double chamber experiments, an additional experiment was designed to measure the hydrostatic pressure at the base of a vertically-oriented plasmodium.

Pressure Measurements. — To measure the pressure in the lower tubes, a vertically migrating culture was oriented through a one inch inflatable rubber cuff connected to a water manometer. After a large tube had formed inside, the cuff was slowly inflated and the pressure changes recorded. The maximum static pressure (i.e., pressure which was maintained over several minutes) was five to six cm of water. Changes in pressure of only two to three cm of water were detected. Two supplemental experiments gave similar results except that the values were lower. A similar experiment was conducted in which a plasmodium was horizontally-

oriented with a tube within the rubber cuff. After the tube was formed, the entire tray was erected so that the plasmodium was in a vertical position, and the pressure measurements then made. The results were the same as for the originally vertically-oriented plasmodium. In addition, no macroscopic change in the appearance of the plasmodium was detected that would have indicated a large change in hydrostatic pressure.

Many authors have described the exudation of protoplasmic drops after the puncture of a plasmodial tube (Belar, 1930; Camp, 1937; Cohen, 1942; Wohlfarth-Bottermann, 1962). A lower tube (approximately 3 mm in diameter) of a vertically-oriented plasmodium was punctured. The resultant drop which flowed out was approximately four mm in diameter and has the same volume as one from a similarly punctured tube of the same size in a horizontally-oriented plasmodium.

Discussion

These studies show that oriented plasmodia develop and maintain a characteristic morphology. Unpublished microscopical studies on oriented plasmodia by Sheen, Miller and Anderson, (1965) have confirmed this morphology. These plasmodia are in a starved condition, and the energy for the protoplasmic movement, and hence the translocation over the agar surface, must result from some autophagous process. The protoplasm of the organism undergoes a sequential change from an advancing front, to a flattened sheet, and to a posterior tubular morphology at a rate which is related to the rate of locomotion of the plasmodium over a surface. These processes appear to be accelerated during starvation of the plasmodium. Conversely, the presence of food materials results in the maintenance of tubes from the plasmodium to the food, and a retardation of migration rates. These observations suggest that the availability of food inhibits the rate of movement and the sequential change in morphology of the organism which is characteristic of locomotion. The results of altering the morphology of a plasmodium indicate that a unified front behaves as the anterior end of a single organism and determines the polarity of a plasmodium.

At intervals the plasmodia interrupted their migration. These results, in agreement with Guttes and Guttes (1963), indicated that plasmodial migration is suspended during the synchronous nuclear divisions which occur in this organism. In addition, the increase in the length of each pause period suggests that the longer a plasmodium is starved, the more the processes required for nuclear division are prolonged, or that perhaps nuclear divisions are becoming less and less synchronous, thereby extending the pause period until all nuclear divisions are completed.

The use of oriented plasmodia to study the pressure developed in vertical versus horizontal situations indicates that in both cases the measurement of hydrostatic pressure is approximately the same and the changes in pressure measured are also the same. These results are in apparent contradiction to both the conclusions of Kamiya (1959) and the concept of a pressure flow mechanism for plasmodial movement. It has occurred to the authors, as it has to others (for example Stewart, 1964), that perhaps the incongruity lies in the previous tacit assumption that the endoplasmic sol is continuous over long distances at the same instant. These experimental results suggest to us that only very limited

volumes of plasmodial endoplasm may be in the sol condition at any one time. If this be the case, then, to some degree, the amount of protoplasm which exudes from a punctured tube could rationally be independent of the height of the tube and dependent upon the limits of solation of the endoplasm in that particular area.

Acknowledgments

This investigation was supported in part by a Public Health Service Fellowship, number NIH-1-F1-GM-23, 041-01 from the Division of General Medicine of the National Institute of Health. In addition, this work was submitted in partial fulfillment of the degree of Doctor of Philosophy at the University of Illinois. Discussions with Dr. Bernard C. Abbott of the Department of Physiology and Biophysics, University of Illinois, contributed significantly to this work.

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Manuscript received January 28, 1966.

CHARACTERISTICS OF A YELLOW BACTERIUM ISOLATED FROM THE TISSUE OF JONATHAN APPLE TREES

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ABSTRACT. — A yellow bacterial isolate obtained from a fire blight canker on the Jonathan cultivar was subjected to the various taxonomic microbiological tests for determining its classification. The yellow isolate was nonpathogenic to Jonathan apple trees. It was gram negative, catalase positive, and peritrichously flagellated. It was rod shaped and ranged from 0.6 to 0.9 microns in width and 1.1 to 2.9 microns in length. The optimum temperature for growth was 25° C with minimum and maximum temperatures for growth at 10° C and 35° C, respectively. This bacterium was nonacid fast, hydrolyzed gelatin but not starch, converted nitrate to nitrite, and produced ammonia but no nitrogen gas. Indole and hydrogen sulfide tests were negative. The methyl red-Voges-Proskauer results were variable. Citrate was able to serve as the sole source of carbon for growth. The protein patterns by disc electrophoresis showed the yellow isolate was distinct from *Erwinia amylovora* and *Escherichia coli*.

This yellow isolate appears to belong in the order Eubacteriales, genus *Erwinia*. However, since it is nonpathogenic to Jonathan apple trees, and shows a different protein pattern it should not be considered as belonging to the genus *Erwinia* at this time.

There has been controversy among many workers (Baldwin and Goodman, 1963; Billing and Baker, 1963; and Goodman, 1965) as to the classification of a yellow bacterium that has been commonly associated with *Erwinia amylovora* (Burrill) Winslow et al., in fire blight cankers.

Therefore, it was decided to study the characteristics of this yellow bacterium in detail and attempt to clarify its taxonomic position.

MATERIALS AND METHODS

Since bacteria may vary from one isolate to another within a species (Rosen, 1928), 20 yellow isolates were obtained from different fire blight cankers of the Jonathan cultivar. Each isolate was considered as a separate entity throughout the entire study. Comparisons were made with known species of *Xanthomonas pruni* (Smith) Dowson; *Erwinia amylovora; Aerobacter aerogenes* (Kruse) Beijerinck; *Proteus vulgaris* (Hauser); *Escherichia coli* (Migula) Castellani and Chalmers; and *Pseudomonas aeruginosa* (Schroeter) Migula.

The procedures used for characterization of the bacteria were obtained from the "Manual of Microbiological Methods" prepared by the Society of American Bacteriologists and will be described with the results given below.

Protein patterns by disc electrophoresis were obtained from the yellow isolate, *Erwinia amylovora*, and *Escherichia coli*. The disc electrophoresis equipment was obtained from the Canal Industrial Corp., Bethesda, Maryland. Approximately 3.0 g of bacteria of each species were harvested from nutrient broth by centrifugation at 5000 x G for 10 minutes. The pellet was washed twice with 30 ml of 0.1 M phosphate buffer (Na_2HPO_4, 21.5g; KH_2PO_4, 5.4 g in 1 liter of distilled water at pH 7.0), and suspended in 5 ml. The bacteria were then sonicated for 7 minutes with a 18 Kc Mullard sonicator and a ¾ inch

probe. The sonicated solution was centrifuged for 1 hour at 60,000 x G. A protein determination (Lowry et al., 1951) was made on the supernatant. The protein solutions were adjusted to 10,000 μg protein to 1 ml with the above buffer and 0.1 ml was added to 1.9 ml of the standard strength stacking gel. Each column received 0.2 ml of the sample gel. The current was adjusted to 6 ma. per tube. When the tracking dye band had moved about 1 inch into the separating gel the columns were removed immediately and placed in ice water. The starch gels were removed from the glass columns and placed in a dye solution for 1 hour and then destained in 7% acetic acid. The protein patterns of the three bacteria were compared visually (Fig. 1).

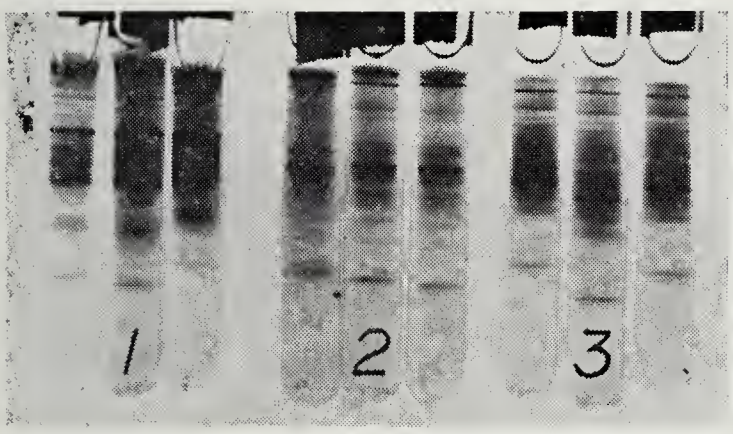

FIGURE 1. — The electrophoretic soluble protein patterns of (1) *E. coli;* (2) *E. amylovora;* (3) yellow isolates.

RESULTS

Pathogenicity tests. — The yellow isolates (hereafter called isolates) were tested for pathogenicity by injecting them as an aqueous suspension into succulent terminal tips of 7-year-old Jonathan apple trees in the field and into 1-year-old Jonathan apple seedlings in the greenhouse. No symptoms developed within 3 weeks after inoculation and thus the isolates were considered nonpathogenic. *E. amylovora*, used as a check, did cause blight symptoms within this period.

Morphology and staining. — All incubations were at 25° C unless noted differently. Cultures were grown on nutrient agar and examined after 24 hours except for the gram stain which was also examined at 12 hours. Heat-fixed films of the isolates were stained by Hucker's modification of the Gram stain and found to be gram negative with some of the bacteria tending to resist decolorization. This phenomenon has been reported by Billing et al. (1961). Size was estimated (using an eyepiece micrometer) by examination of heat-fixed films stained with the methylene blue solution used in the Gram stain. The isolates were rods of irregular length which usually occurred singly, occasionally in pairs and short chains. They varied from 0.6 to 0.9 microns in width and 1.1 to 2.9 microns in length. The isolates were observed as living bacteria in a hanging drop and to demonstrate flagella, Bailey's method as modified by Fisher and Conn was used All the isolates had 1 to 5 flagella arranged peritrichously. An acid fast stain was made using the Ziehl-Nelsen method and the amended formula of the carbol-fuchsin solution for staining. Isolates were all nonacid fast.

Colony form. — The isolates were incubated on nutrient agar in slanted test tubes and examined after 24 hours and at the end of 1 month. Growth was filiform and the streak a glistening yellow. The margins were thickened and had very fine serrations at the outermost edges. After one month a very viscous slime had accumulated at the bottom of the slant.

Oxygen requirement. — Glucose nutrient agar deeps were made by filling test tubes to a depth of 9 cm with nutrient agar containing 1% glucose. Before the medium solidified, a drop of a nutrient broth suspension from 24-hour-old nutrient broth cultures was added. The tubes were examined after incubation for 1 week. No growth occurred except in the top 1.5 cm of the medium and thus the isolates were considered aerobes.

Optimum temperature. — Each tube was inoculated with one drop from 24-hour-old nutrient broth cultures. The tubes were incubated at 10, 15, 20, 25, 30, and 35° C and the amount of growth was determined by measuring the optical density using a spectrophotometer set at a wave length of 660 millimicrons. Readings were made at 0, 12, 24, and 48 hours after inoculation. The above was repeated twice and the average optical density computed for each temperature and isolate. Maximum growth was at 25° C. At 30° C the growth was less than at 25° C, but considerably better than at 20° C. Some growth occurred at both 10° and 35° C.

Utilization of citrate. — Test tubes containing Koser's citrate broth were inoculated in duplicate with 1 drop of

broth from 24-hour-old nutrient broth cultures. After 7 days of incubation the tubes were checked for cloudiness. The isolates were able to utilize citrate as the sole carbon source.

Hydrolysis of starch. — Cultures were streaked onto 0.2% starch-nutrient agar and incubated for 1 week. Gram's modification of Lugol's iodine solution was used to detect starch hydrolysis. The isolates were not able to hydrolyze starch.

Gelatin liquefaction. — Two methods were used. Stab cultures were made into tubes containing 12% gelatin and incubated at 20° C for 6 weeks. Cultures were also streaked across a 0.4% gelatin-nutrient agar and incubated at 28° C for 2 weeks. After incubation the surface of the medium was flooded with a solution of acid mercuric chloride. The results of both tests indicated all isolates except No. 4 were able to liquefy gelatin.

Catalase production. — About 1 ml of 10% hydrogen peroxide was added to 24-hour-old cultures on nutrient agar. All isolates were catalase positive.

Nitrate reduction. — Two methods were used. Tubes of nitrate broth were inoculated and strips of red litmus paper were placed inside the tubes near the top to check for ammonia production. Ammonia was formed by all isolates. Nitrate agar was also used. Incubation was for 12 days for both procedures. Zinc dust was added to nitrate agar tubes giving negative results to verify that nitrate remained and had not been decomposed beyond the nitrite stage. All isolates except Nos. 4 and 10 formed nitrite within 48 hours. After 12 days of incubation Nos. 4 and 10 were only slightly positive indicating they were very poor nitrate reducers.

Indole production. — Broth composed of 1% trypticase was the medium used. Kovac's test was used to determine the presence of indole after 1, 3, 5, and 11 days. None of the isolates were able to produce indole.

Methyl Red (MR) and Voges-Proskauer (V-P) tests. — The medium contained 7 g trypticase, 5 g K_2HPO_4, and 5 g glucose per liter of distilled water. Duplicate tubes were used and after incubation for 7 days several drops of a methyl red solution were added to one set of tubes. Only isolate Nos. 9, 19, and 20 gave a positive methyl red test. The V-P test for acetoin was performed by adding 0.6 ml of 5% alpha naphthol in absolute ethanol and 0.2 ml of a 40% KOH and 0.3% creatine solution to 1 ml of the 7-day-old broth cultures. After 1 minute of vigorous agitation the tubes were allowed to sit 10 minutes and then observed for development of a pink color. Isolate Nos. 4, 9, 10, 15, and 17 formed acetoin whereas the other 15 isolates could not do so.

Litmus milk test. — Medium was prepared by adding 5 g of litmus to 1 liter of 10% Bacto Skim Milk. Readings were made after 7 days of incubation. The results of this test were extremely variable in regards to pH, oxidation-reduction potential, and the appearance of the milk itself. Isolate Nos. 4, 10, 15, and 17 caused a basic reaction in the medium. Isolate No. 17 also reduced the litmus. Isolate Nos. 5, 7, and 19 were acid in reaction.

A summary of the above tests is shown in Table 1. The results indicated that the 20 yellow isolates were the same species and were treated as such in Table 1.

Electrophoresis. — Soluble protein fractions from *E. coli*, *E. amylovora*, and one of the isolates were separated by electrophoresis. The protein bands were stained and the resulting protein patterns of the various bacteria compared visually (Fig. 1). The results obtained indicate that the isolates and *E. amylovora* are not the same species and both were distinct from *E. coli*.

Discussion

In comparing the test results of the 20 isolates with the report of Farabee and Lockwood (1958) it was noted that their isolates were gram positive and could not reduce nitrate. On this basis the 20 yellow isolates used in this study are not the same as those of Farabee and Lockwood which they classified as *Bacterium*.

The 20 yellow isolates might be the same as those of Goodman (1965) but other than the fact that they were both yellow, gram negative, and had peritrichous flagella, insufficient information was given by him for comparison. Baldwin and Goodman (1963) and Goodman and Shaffer (1963) also showed the yellow bac-

terial cultures sensitive to 2 of 5 *E. amylovora* phages as well as to a 35A-Y phage. Virulent white isolates were sensitive to all 5 of the *E. amylovora* phages but not the 35A-Y phage. From these later results Goodman (1965) decided the relationship between *E. amylovora* and the yellow bacterium was not clear.

Comparison of the results obtained from the authors' 20 yellow isolates with those obtained by Billing and Baker (1963) indicated that both probably are of the same species. To be certain, however, the tests would have to be repeated using the procedures of Billing and Baker (1963) on both the authors' isolates and those of Billing and Baker.

Considerable confusion was found in the older literature concerning yellow gram negative bacteria. James, in 1955, reported "There is little doubt that the yellow chromogen referred to in this report is the

TABLE 1. — A Comparison of the Biochemical Reactions of Yellow Bacteria Isolated from Fire Blight Cankers and Six Known Species of Bacteria. Reaction Symbols are: A, aerobic; +, positive; —, negative; V, variable.

Test	Yellow isolates	*Erwinia amylovora*	*Xanthomonas pruni*	*Proteus vulgaris*	*Aerobacter aerogenes*	*Escherichia coli*	*Pseudomonas aeruginosa*
Stains							
gram	—	—	—	—	—	—	—
acid fast	—	—	—	—	—	—	—
Hydrolysis of							
starch	—	—	+	—	—	—	—
gelatin	+	+	+	—	—	—	+
Oxygen requirement	A	A	A	A	A	A	A
Nitrate test							
NO_3 to NO_2	+	—	—	+	+	+	+
NH_3 formed	+	+	+	+	+	+	+
gas (N_2)	—	—	—	—	—	—	—
Indole	—	—	—	+	—	+	—
H_2S	—	—	—	+	—	—	+
Citrate	+	—	—	—	+	—	+
Methyl red	V	—	—	+	—	+	—
Voges-Proskauer	V	—	—	—	+	—	—
Catalase	+	+	+	+	+	+	+

same as that described by Dugelli, and by Huss and studied in more detail by Mack." He proposed the name *Xanthomonas trifolii* for his yellow bacteria. Billing and Baker (1963), however, have cited reasons for doubting that his cultures were the same.

Hayward and Hodgkiss (1961) have shown that the yellow pigmented bacterium, *Xanthomonas uredovorus*, which originally was thought to possess a single polar flagellum, was found to possess peritrichous flagella. They also proposed that this organism should be transferred to the genus *Erwinia*.

Thus, as a result of this confusion, Billing and Baker (1963) considered their isolates to be members of a poorly defined '*lathyri-herbicola*' group within the genus *Erwinia*.

Bergey's manual (Breed et al., 1957) states that all peritrichously flagellated bacteria are classified in the order Eubacteriales. Further checking of the keys with the test results obtained from the 20 yellow isolates leads to the genus *Erwinia*. With the present classification system the genus *Erwinia* is reserved for organisms which are plant pathogens (Breed et al., 1957). This bacterium, since it is nonpathogenic, can not be properly classified until either a new genus is formed, a host is found, or until the present requirements of the genus *Erwinia* are modified to include nonplant pathogens.

Characterization of bacteria by electrophoretic separation has not been utilized extensively (Rodenberg, 1959). Based on the protein patterns the isolates are definitely not the same species as *E. amylovora* (Fig. 1).

Acknowledgments

The authors wish to thank Dr. F. M. Clark of the University of Illinois, Department of Microbiology, for supplying some of the bacterial cultures and Dr. H. S. Gill for technical assistance on the electrophoresis determinations.

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Manuscript received May 10, 1966.

THE EFFECT OF LIGHT ON THE AMINO ACID METABOLISM OF *DIPLODIA ZEAE*

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ABSTRACT. — Mycelial extracts and culture media from *D. zeae* grown simultaneously on a rotary shaker in the light and dark were assayed for qualitative amino acid content. A distinct difference was found in amino acid content of media from light-grown and dark-grown cultures, with very little difference in the mycelium.

Several studies have been conducted concerning the amino acid metabolism of fungi. Woolley and Peterson (1936) were the first to analyze the free amino acids found in the mycelium. Since that time, other workers have studied amino acid content in spores, mycelial hydrolysates and extracts, and also in culture media (Broyles, 1952; Murray and Zschiele, 1956; DeVay, 1952, 1954; and Jones, 1963). Pillai and Srinivason (1956), working with *Aspergillus flavus*, investigated the free amino acid content of mycelium, acid hydrolysate of mycelial residues, and the released free amino acids in the culture medium over a 30 day period of time. The effect of light on the amino acid metabolism has not been considered by any of these investigators.

A recent review of photobiology of fungi has been presented by Carlile (1965). Several areas of photobiology were discussed. Work with the watermold *Blastocladiella emersoni* by Cantino and coworkers showed an increased growth rate in illuminated cultures in contrast to unilluminated cultures. This increased rate of growth was accompanied by an increase in carbon dioxide fixation and polysaccharide synthesis. In addition, a definite effect of light on various enzymes produced by the fungus that are involved in a succinate-α-ketoglutarate-isocitrate cycle, nucleic acid biosynthesis, and arginine metabolism was demonstrated. Growth of another watermold, *Thraustochytrium roseum*, has been reported by Goldstein (1963) to be stimulated by light.

The limited work with light effects on filamentous fungi was also reviewed by Carlile. The growth rate of *Sclerotina fructigena* on malt agar is much higher in the light, while growth of *Penicillium clavigerum* on Czapek agar was depressed by light. The response to light differed in various types of medium. Carlile suggests that under optimal growth conditions the light and dark metabolism of many species is equally effective, but that under suboptimal growth conditions the fungi are more subject to metabolic changes induced by light or dark conditions. Katsanos and Pappelis, in unpublished

work in this laboratory, have found a two-fold increase in fresh weight in light-grown cultures of *D. zeae* over dark-grown cultures.

Light effects on sporulation also have been reported. Kaiser (1964), working with *Verticillium alboatrum,* observed a blue light inhibition of microsclerotium formation. Whitney (1964) and Robbins and Hervey (1960) reported light inhibition of basidia formation in *Rhizoctonia solani* and *Poria ambigua,* respectively.

The biochemical processes effected by light in these filamentous fungi have not been elucidated. In the present work, the effect of light on amino acid synthesis and their release into the culture medium by *Diplodia zeae* (Schw.) Lev. over a period of time was investigated. It is a preliminary attempt to more carefully determine the effect of light on *D. zeae* and its possible effect on pathogenicity in roots or stalks of corn.

Methods and Materials

Inoculum for this study was prepared by transferring a piece of mycelium with underlying agar (5 mm approximate diameter) from a potato dextrose agar plate into a 125 ml Erlenmeyer flask containing 50 ml of Czapek-dox broth medium (pH 4.5 after autoclaving). After a 5 day incubation period, the liquid medium was decanted and the mycelium fragmented for 1.5 minutes in a sterile, semi-micro Waring Blendor cup containing 50 ml of sterile, distilled water. Three ml of this suspension was transferred to several 125 ml Erlenmeyer flasks each containing 50 ml of Czapek-dox medium. One half of the flasks were wrapped with aluminum foil for the dark study. All flasks were placed on an illuminated rotary shaker (Pappelis, et al., 1964) operating at 105 r.p.m. at room temperature (25 - 28°C). Three flasks each of mycelium grown in the light and in the dark were removed for amino acid extraction and determination at 2, 4, 8, and 10 days of incubation.

The cultures were filtered separately on Buchner funnels with reduced pressure. Filtrates were removed for study before the mycelium was washed. Three volumes of 95% ethanol were added to the syrup-like filtrate and heated to boiling to precipitate the proteins. This mixture was transferred to centrifuge bottles and spun at 3,000 r.p.m. The supernatant was brought down to a volume of 10 ml using a rotary flash evaporator. Further purification of the medium was found to be necessary since carbohydrates interfered with the amino acid separation on the paper chromatograms. The ion-exchange method of purification described by Thompson, Morris and Gering (1959) was used. The eluates from the columns were evaporated to a 2 ml volume.

The mycelial mats obtained from filtration were quickly washed with 50 ml of normal saline and refiltered. This was done three times. The washed mycelial mats were transferred to a glass mortar and homogenized in 80% ethanol. After heating to boiling, the extract was cooled and centrifuged at 3,000 r.p.m. The supernatant was evaporated to dryness, and the residue made up to a volume of 2 ml with 10% ethanol. Ion exchange purification was not necessary since no interference of separation was observed on paper chromatograms.

Two-directional, descending paper chromatography of 25 lambda of extract using 23″ x 23″ Whatman #3 paper was employed to separate the amino acids. Phenol (Chromatography grade, liquefied): water (4:1 v/v) was used as the first-direction solvent; butanol: acetic acid: water (9:1:2.5 v/v/v) as the second-direction solvent. The first solvent was allowed to run for 24 hours, and the papers were dried at room temperature (25 - 28°C) for another 24 hours. The second direction also was run for 24 hours and dried 5 to 10 hours.

The spray reagent used, a modification by Ramon Tate (unpublished) of the Moffat and Lytle (1959) color reagent, formed various shades of reds, blues and tans characteristic for each amino acid. Two stock solutions were prepared consisting of (1) 1% (w/v) cupric nitrate in acetone and (2) 0.2% w/v ninhydrin and 1% (v/v) acetic acid in acetone. Immediately before spraying the 1% cupric nitrate was

diluted to 0.03% with acetone and mixed with an equal volume of the ninhydrin stock solution. The papers were dried and the colors developed by heating. The R_f values and colors were compared to known standards determined using the above procedures singly and in mixtures.

Results

The free amino acid content of the mycelium and of the culture media is presented in Table 1. Qualitatively, the amino acids were essentially the same in the mycelium of light-grown and dark-grown cultures, except for the later appearance of lysine in the mycelium grown in the dark. A similar, unidentified spot was found on chromatograms of both extracts at 4, 8, and 10 days. Also, one more unidentified ninhydrin spot was present on the chromatograms of the dark culture at 4, 8, and 10 days.

Analysis of the culture media revealed a distinct difference in the amount of

Table 1. — Free amino acids present in the culture media and mycelial extracts of *D. zeae* grown in the light and in the dark at 2, 4, 8, and 10 days of incubation.

Amino Acid	Mycelial Extract								Culture Media							
	Light				Dark				Light				Dark			
	2	4	8	10	2	4	8	10	2	4	8	10	2	4	8	10
∝ alanine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
arginine											+	+				
asparagine		+	+	+		+	+	+			+	+			+	+
cysteine-cystine		+	+	+		+	+	+								
glutamine											+	+				
glutamic acid	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
glycine		+	+	+		+	+	+	+	+	+		+			
histidine	+	+	+	+	+	+	+	+		+	+	+				
leucine-isoleucine		+	+	+		+	+	+			+	+				
lysine	+	+	+	+		+	+	+								
methionine		+	+	+		+	+	+		+	+	+				
proline		+	+	+		+	+	+			+	+				
serine	+	+	+	+		+	+	+					+			
threonine		+	+	+		+	+	+			+	+				
tryptophan												+				
tyrosine		+	+	+		+	+	+								
valine		+	+	+		+	+	+								

amino acids released into the medium under the different light conditions. In the light-grown cultures, nearly all of the amino acids found in the mycelium were gradually released into the medium with the exception of cysteine-cystine, serine, tyrosine, and valine. Arginine, glutamine and tryptophan were found in the medium but not in the mycelium. In the dark-grown cultures, only ∝-alanine, asparagine and glutamic acid accumulated in the medium at 10 days. Glycine and serine appeared only in the two-day culture; serine never appeared in medium from light-grown cultures. The total accumulation at 10 days in the light was 12 amino acids and in the dark only 3.

Discussion

When the data from this study are compared with those of Pillai and Srinivason (1956), similarities are noted in that the mycelium contains more free amino acids than does the culture medium. However, it is not advisable to compare differences between the data regarding free amino acid content in the culture medium of light and drak grown mycelium to that grown under laboratory conditions where alternating light and dark occurs, since, as our data have shown, the difference is considerable. In future studies directed to free amino acid or protein content in the mycelium or the cultural medium, light should be regarded as an important variable requiring control.

Whether the difference observed in amino acid release into the culture medium is due to an alteration of protein synthesis thereby altering the requirements of the amino acid pool, or due to a stimulation of amino acid biosynthesis is yet to be investigated.

The various effects of different wavelengths of light also are to be considered. Kaiser (1964) observed microsclerotia formation at several wavelengths and noted distinct differences not only in the microsclerotia, but also in pigmentation. An investigation of this sort would be a further aid in elucidation of the mechanisms of light action on amino acid synthesis and release by *D. zeae*.

Acknowledgments

This study was supported in part by a grant from the National Science Foundation (GB-1072).

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Manuscript received July 12, 1966.

BOTANICAL FIELD STUDIES IN THE SOUTHERN TIP OF ILLINOIS

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ABSTRACT. — Intensive botanical field work in Pope, Johnson, and Massac counties revealed several unusual records for Illinois vascular plants. Reported as new to Illinois are *Cornus amomum*, *Panicum condensum*, *Panicum hians*, and *Panicum stipitatum*. Other new or rare southern Illinois species are recorded.

This paper reports the results of intensive botanical field work in Pope, Johnson, and Massac counties during 1965. Several areas seldom visited by botanists provided a few new records for Illinois and numerous local records. The state records and the more significant local records are enumerated in this paper. One record from adjacent Alexander County is reported. All specimens are in the herbarium of Southern Illinois University (SIU). The map, showing the collecting sites listed in this paper, was prepared by the Cartographic Office, Mississippi Valley Investigations, Southern Illinois University (Fig. 1). A description of three of these areas follows:

Mermet Wildlife Refuge is a state-maintained conservation area of low, marshy woods surrounding a sluggish fishing lake in Massac County. The lake supports such vegetation as *Limnobium spongia*, *Utricularia gibba*, and *Jussiaea diffusa*. In several areas the lake margin merges into a swampy woods. In one such area, two unusual Illinois shrubs occur. These are the virginia willow (*Itea virginica*) and storax (*Styrax americana*). In another such area, a large stand of royal fern (*Osmunda regalis*) occurs on the forest floor. Such a habitat for this usually moist cliff-ledge species of southern Illinois is

1 - Panicum hians
2 - Panicum stipitatum
3 - Split Rock Hollow
4 - Rock (village) and Millstone Knob
5 - Mermet Wildlife Refuge
6 - Cornus amomum
7 - Old Baldy
8 - Massac Tower

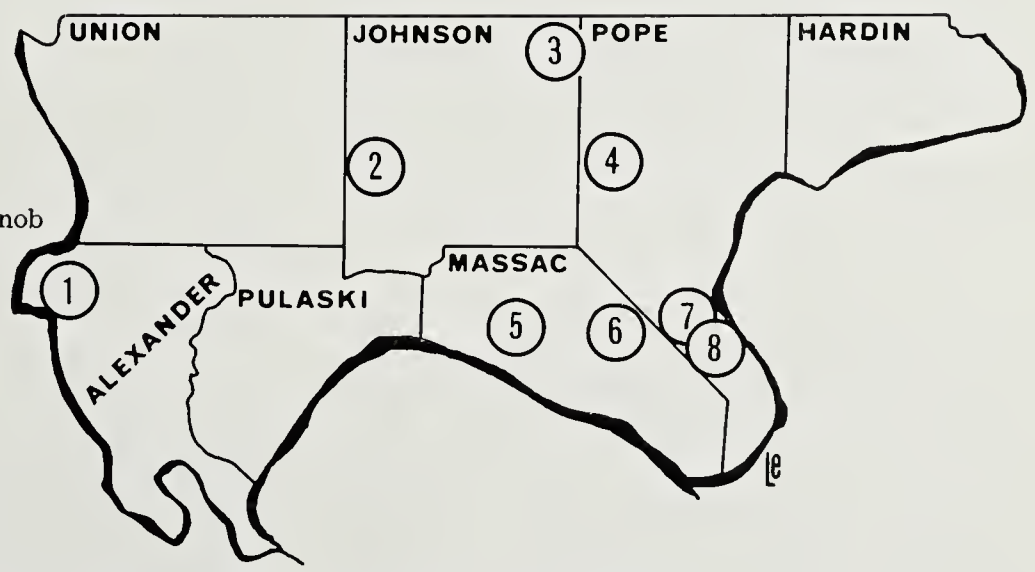

FIGURE 1. — Map of the seven southern counties in Illinois.

unusual, although this is a typical habitat for this fern in northern Illinois. *Rhynchospora corniculata* occurs along the lake's edge in several places; handsome specimens of willow oak (*Quercus phellos*) and swamp cottonwood (*Populus heterophylla*) may be found. Records of more unusual species are enumerated below.

Old Baldy is a xeric hilltop which lies about four miles southwest of Bay City in Pope County. It is underlain by permeable gravel of Pliocene age, which together with the steepness of slope produces an interesting dry habitat. The southwest slope supports a few stunted xeric oaks, but most of the area is unshaded. Topsoil is thin at best, with patches of barren gravel exposed. Several records of interest are reported below.

A magnificent marshy woods at Massac Tower, near the Pope-Massac county line in Pope County, has provided several new records of Illinois flowering plants. The woods is extremely spongy underfoot and supports a vegetation community unlike any seen elsewhere in southern Illinois. Huge stands of royal fern, cinnamon fern (*Osmunda cinnamonea*), and sensitive fern (*Onoclea sensibilis*) intermingle with marsh fern (*Thelypteris palustris*) and purple fringeless orchid (*Habenaria peramoena*). Rare species are listed below.

Species New to Illinois

Cornus amomum Mill. Massac: Mill Spring, 3½ miles southwest of Bay City, June 6, 1965, *John Schwegman s.n.* Flowering specimen, occurring in low woods.

Panicum condensum Nash. Massac: Mermet Wildlife Refuge, low swampy woods, June 27, 1965, *R. H. Mohlenbrock 12626.* Growing with *Carex louisianica*, *C. grayi*, and *C. muskingumensis*. Although Fernald (1950) records this from southern Illinois as *P. agrostoides* var. *condensum*, we have seen no Illinois collection other than the one reported here.

Panicum hians Ell. Alexander: low, swampy roadside ditch, along Illinois Route 3, vicinity of Gale, June 30, 1965, *R. H. Mohlenbrock 1300f.*

Panicum stipitatum Nash. Johnson: one mile west of West Vienna, June 27, 1965, *R. H. Mohlenbrock 1263f.* In swampy woods beneath *Planera aquatica* and *Itea virginica.*

Species New to Southern Illinois

Panicum wilcoxianum Vasey. This grass was found on dry gravel hilltops associated with *Polygala incarnata* and *Lechea villosa.* This station is over 300 miles south of the nearest previous Illinois record (Winterringer and Evers, 1960). COLLECTION DATA: Old Baldy, four miles southwest of Bay City, Pope County, August 3, 1965, *Schwegman 76.*

Habenaria clavellata (Michx.) Spreng. Nine plants of this rare orchid were found growing in damp soil in woods. *Osmunda regalis* and *O. cinnamomea* are associates at this station. This is the fourth record from Illinois and the first this century. COLLECTION DATA: Massac Tower, Pope County, July 18, 1965, *Schwegman 36.*

Spiranthes vernalis Engelm. and Gray. This ladies'-tresses is one of the rarer orchids in Illinois. A collection from Effingham County is the only previous Illinois record for it since the turn of the century. At both southern Illinois stations it is associated with *Andropogon scoparius* in abandoned fields. COLLECTION DATA: Rock, Pope County, August 7, 1964, *Schwegman s.n.*; Mermet Refuge, Massac County, June 22, 1965, *Schwegman & Montgomery 48.*

Polygala incarnata L. This species is known from several central and northern Illinois counties, but had never been found south of Morgan County, some 200 miles to the north. In southern Illinois it grows on hilltops in gravelly soil. COLLECTION DATA: Old Baldy, four miles southwest of Bay City, Pope County, August 3, 1965, *Schwegman 75.*

Lechea villosa Ell. This species was found on dry hilltops in woods. It is

basically a northern species, with a record from St. Clair County being the southernmost previously. COLLECTION DATA: Old Baldy, four miles southwest of Bay City, Pope County, August 3, 1965, *Schwegman 74*; one-half mile south of Old Baldy, Massac County, August 3, 1965, *Schwegman s.n.*

Additional Localities for Rare Southern Illinois Species

Isoetes melanopoda Gay and Dur. Dwarf specimens (4-8 cm tall) of this quillwort were growing with *Eleocharis acicularis* in marshy clay in a low woods on the Mermet Wildlife Refuge. COLLECTION DATA: low woods, Mermet Wildlife Refuge, Massac County, May 28, 1965, *R. H. Mohlenbrock 16011.*

Asplenium X *ebenoides* Scott. This hybrid between *A. platyneuron* and *A. rhizophyllum* was known previously in Illinois from Jackson and Pulaski counties. It has now been found in a woods in Pope County. COLLECTION DATA: woods, near Rock, Pope County, June 6, 1965, *John Schwegman s.n.*

Chamaelirium luteum (L.) Gray was found growing with mosses on sandy banks of a dry stream bed. The station is in dry oak-hickory woods. Dozens of plants occur at this station. The species was previously known in Illinois only from Massac and Hardin counties (Mohlenbrock and Voigt, 1959). COLLECTION DATA: Massac Tower, Pope County, July 25, 1965, *Schwegman 55.*

Iris cristata Ait. Dwarf crested iris has been known in Illinois only from Hardin and Union counties (Mohlenbrock and Voigt, 1959) where it grows on stream banks. At both stations cited here, it grows in woods on slopes of north-facing hills as well as stream banks. COLLECTION DATA: Massac Tower, Pope County, July 25, 1965, *Schwegman 54*; Mermet Refuge, Massac County, August 3, 1965, *Schwegman 78.*

Tipularia discolor (Pursh) Nutt. Crane-fly orchid was first collected in Illinois in 1959 (Mohlenbrock and Voigt, 1959a) at Jackson Hollow in Pope County. Since then, it has been collected at several other stations in that county. This report is the first for it outside of Pope County. COLLECTION DATA: Split Rock Hollow, two miles south of Ozark, Johnson County, May 1, 1965, *Schwegman s.n.*

Hypericum denticulatum Walt. This species has been found previously in Illinois only from two stations in Pope County. Now a third station in Pope County may be recorded. COLLECTION DATA: dry hilltop, Old Baldy, four miles southwest of Bay City, Pope County, August 3, 1965, *John Schwegman 77.*

Monotropa lanuginosa Michx. Pinesap was found growing on a dry oak-hickory hillside in a colony of more than 70 plants. It was previously known in southern Illinois only from Jackson County (Mohlenbrock and Voigt, 1959). COLLECTION DATA: Massac Tower, Pope County, September 25, 1965, *Martha Schwegman (John Schwegman 126).*

Gerardia fasciculata Ell. This southeastern species was first collected in Illinois in 1958 by Mohlenbrock (Winterringer and Evers, 1960) in Jackson County. In Massac County it grows on a roadside in the Mermet Wildlife Refuge. COLLECTION DATA: Mermet Refuge, Massac County, August 28, 1965, *Schwegman 113.*

Scutellaria nervosa Pursh. f. *alba* Palmer & Steyerm. This white-flowering color form has been known previously from one station in Missouri and one in a low woods at Lake Murphysboro State Park, Jackson County, Illinois. This taxon has now been discovered in a swampy woods in Massac County. COLLECTION DATA: Mermet Wildlife Refuge, Massac County, May 28, 1965, *R. H. Mohlenbrock 16002.*

Helianthus angustifolius L. This narrow-leaved sunflower was first found in Illinois in Massac County by R. A. Evers in 1957. Now another collection from Massac County has been made. COLLECTION DATA: Mermet Wildlife Refuge, Massac County, August 28, 1965, *John Schwegman s.n.*

Rudbeckia missouriensis Engelm. Evers had previously found this species on the limestone hill prairies of Monroe and Randolph counties. Now Pope County may be added. COLLECTION DATA: Millstone Knob, Pope County, July 17, 1965, *John Schwegman 41.*

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Manuscript received April 5, 1966.

VARIOUS METHODS OF SOLVING A FIRST ORDER PERTURBATION EQUATION

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ABSTRACT.—A general procedure is described for obtaining the complementary function of a linear, second-order, inhomogeneous differential equation. This method is applicable to a majority of the radial equations of quantum theory. Three methods of finding the particular integral are discussed. The techniques are unified by the use of an example from perturbation theory.

The purpose of this paper is to present and compare several methods of solving a differential equation which occurs in quantum mechanical problems. None of the techniques are new but this paper presents them in such a manner that a beginner can choose the best method for his problem. Further, no completely worked out example is available in the literature so that the present paper provides a guide post for the beginning research worker. The example which is used occurred in a perturbation treatment of the refractive index of helium (Musulin and Epstein, 1964).

PRELIMINARIES

Since the notation of that report is unduly cumbersome for illustrating the points in the solution of a single differential equation, the following changes are made (the new notation appearing on the right).

$$H_{00} = H_0 \qquad g_1^{(0)} = g$$

$$E_0^{\,0} = E_0 \qquad g_2^{(0)} = f$$

$$\Psi_{0\pm0} = \Psi^0$$

$$\Psi_{1+0}{}^{(0)} = \Psi^1$$

$$G^+ = V$$

Throughout this report Hartree atomic units are used (1 bohr = 0.52917 Å and 1 hartree = 27.2097 e.v. (Manne, 1963)).

The Basic Equations.—The basic equations resulting from a triple perturbation in time, $^1/\zeta$, and ω (the angular frequency) are

$$(H_0 - E_0)\ \Psi^0 = 0 \qquad (1)$$

$$(H_0 - E_0)\ \Psi^1 = -V\Psi^0$$

where $H_0 = h_1 + h_2$

$$= [-\tfrac{1}{2}\nabla_1^2 - \zeta/r_1] + [-\tfrac{1}{2}\nabla_2^2 - \zeta/r_2]$$

$$E_0 = -\zeta^2/n^2$$

$$\Psi^0 = \Psi_1\,\Psi_2$$

$$= \left[\left(\frac{\zeta^{3/2}}{\sqrt{\pi}}\right)e^{-\zeta r_1}\right]\left[\left(\frac{\zeta^{3/2}}{\sqrt{\pi}}\right)e^{-\zeta r_2}\right]$$

$$V = V_1 + V_2$$

$$= [-r_1 P_1(\cos\theta_1)] + [-r_2 P_1(\cos\theta_2)]$$

The electric field, $\mathcal{E}$, which multiplies V_1 and V_2 is omitted since it may be considered as a perturbation parameter.

Partial Legendre Expansion.—The solution of Equation (1) is now discussed

in detail. This problem is reduced to a problem of obtaining appropriate radial functions after Ψ^1 is partially expanded in Legendre Polynomials (Hirschfelder, *et. al.*, 1963, pp. 30-31). In this case

$$\Psi^1 = [g(r_1)P_1(\cos\theta_1)\,P_0(\cos\theta_2) + g(r_2)P_0(\cos\theta_1)\,P_1(\cos\theta_2) + f(r_1)P_0(\cos\theta_1)\,P_0(\cos\theta_2) + f(r_2)P_0(\cos\theta_1)\,P_0(\cos\theta_2)]\,\Psi^0 \quad (2)$$

Substitution of Equation (2) into Equation (1) leads, after the appropriate integrations, to

$$-\frac{1}{2}g''(r_i) - \frac{1}{2}\left(\frac{2}{r_i} - 2\zeta\right)g'(r_i) + \frac{1}{r_i^2}g(r_i) = r_i \quad (3)$$

$$-\frac{1}{2}f''(r_i) - \frac{1}{2}\left(\frac{2}{r_i} - 2\zeta\right)f'(r_i) = K \quad (4)$$

where i takes the values 1 and 2. The remainder of the report illustrates the different approaches to solving Equation (3).

It should be pointed out that the same techniques which solve Equation (3) prove that the only acceptable solution for Equation (4) is

$$f(r_i) = 0$$

However, it should be emphasized that in many instances it is not necessary to obtain a formal solution for every unknown radial function. A particular problem should be first analyzed to see if each term of the partial Legendre expansion contributes to the matrix elements to be evaluated.

Confluent Hypergeometric Equation

Recognizing the Equation.—Equation (3) is characterized as a linear, second-order differential equation. It is also called an inhomogeneous differential equation because the term appearing on the right hand side contains neither the unknown function g or its derivatives. It can also be remarked that Equation (3) is not an eigenvalue equation.

The solution of an inhomogeneous differential equation relies heavily upon the solution of the associated homogeneous equation; that is, the equation whose right hand side is zero. For the sake of clarifying notation, the unknown function in the associated homogeneous equation is designated by G(r).

The homogeneous equation associated with Equation (3), after multiplication by -2, is (dropping the variable subscripts for convenience)

$$G''(r) + \left(\frac{2}{r} - 2\zeta\right)G'(r) - \frac{2}{r^2}G(r) = 0 \quad (5)$$

The general second-order linear differential equation can be written

$$y'' + P(x)y' + Q(x)y = X(x) \quad (6)$$

The substitution (Burington and Torrance, 1939),

$$y = e^{-\frac{1}{2}\int P dx}w \quad (7)$$

changes Equation (6) into a second order linear differential equation which does not contain terms in the first derivative. Although the general solution of Equation (3) is not readily recognized, often, the equation, which results from a transformation of the type given in Equation (7), for radial problems is a standard differential equation. In particular, it is the differential equation whose solution is the confluent hypergeometric function (4).

For equation (3) the substitution

$$G = \frac{1}{r}e^{\zeta r}w \quad (8)$$

carries equation (5) into

$$w'' + \left[-\zeta^2 + \frac{2\zeta}{r} - \frac{2}{r^2}\right]w = 0 \quad (9)$$

which is a hybrid standard form. The standard equation is usually written

$$w'' + \left[-\mu^2 + (\gamma - 2\alpha)\frac{\mu}{r} + \frac{\gamma(2-\gamma)}{4r^2}\right]w = 0 \quad (10)$$

Another transformation results from the change of variable in Equation (9)

$$z = 2\zeta r$$

which gives

$$w'' + \left[-\frac{1}{4} + \frac{1}{z} - \frac{2}{z^2} \right] w = 0 \quad (11)$$

The corresponding standard form, Whittaker's equation, (Jeffreys and Jeffreys, 1950) is

$$w'' + \left[-\frac{1}{4} + \frac{k}{z} + \frac{\frac{1}{4} - m^2}{z^2} \right] w = 0 \quad (12)$$

Finally, a third transformation results from substituting in Equation (11)

$$w = e^{-\frac{1}{2}z} z^2 u \quad (13)$$

which yields

$$zu'' + (4 - z)u' - u = 0 \quad (14)$$

and this corresponds to the standard form, Kummer's equation, (Jeffreys and Jeffreys, 1950)

$$xu'' + (\gamma - x)u' - \alpha u = 0 \quad (15)$$

Although it is often more convenient to use the solutions to Kummer's equation, it is usually more direct to proceed to Equation (10) which is a variant of Whittaker's equation. Consequently, the solutions to both Equations (12) and (15) are now discussed.

The Kummer Solutions.—Comparing Equations (14) and (15), one finds

$$\gamma = 4 \qquad \alpha = 1$$

Four possible solutions to Equation (14) are

$$u_1 = {}_1F_1(1,4,z)$$

$$u_2 = z^{-3}{}_1F_1(-2,-2,z)$$

$$u_3 = U(1,4,z)$$

$$u_4 = z^{-3}U(-2,-2,-z)$$

where ${}_1F_1(\alpha,\gamma,x)$ is the confluent hypergeometric function and $U(\alpha,\gamma,x)$ is its associated function. Any two of these four solutions are linearly independent but any three solutions are linearly dependent. By means of special transformations there are four alternate ways of writing the solutions u_1, u_2, u_3, and u_4 (Slater, 1950). These forms are not of interest in the present discussion but they do bring one's supply of functions, from which to choose the two linear independent solutions, to eight. Two of the solutions, u_2 and u_3, can be written in closed form. Since $\alpha = \gamma$ in u_2, (Erdelyi, *et. al.*, 1953)

$${}_1F_1(-2,-2,z) = e$$

Then

$$u_2 = \frac{1}{z^3} e^z$$

and

$$G_1 = \frac{2\zeta}{z^2} \quad (16)$$

where the subscript is used to identify a specific solution of the homogeneous equation (5).

That u_3 is in closed form can be seen from the integral representation (Jeffreys and Jeffreys, 1950).

$$U(\alpha,\gamma,x) = \frac{1}{(\alpha-1)!} x^{1-\gamma} \int_0^\infty \frac{e^{-\mu}\, \mu^{\alpha-1}}{(x+\mu)^{\alpha-\gamma+1}}\, d\mu \qquad R(\alpha) > 0$$

Hence

$$U(1,4,z) = \frac{1}{z} + \frac{2}{z^2} + \frac{2}{z^3}$$

and

$$G_2 = 2\zeta \left[1 + \frac{2}{z} + \frac{2}{z^2} \right] \quad (17)$$

It is well to note at this point that G_2 is well behaved at $r = \infty$ but not at $r = 0$ while G_1 becomes infinite both at $r = 0$ and $r = \infty$. A solution which is well behaved at $r = 0$ but not at $r = \infty$ is based upon u_1, i.e.

$$G_3 = 2\zeta z\, {}_1F_1(1,4,z) \quad (18)$$

Expansion of the exponential in Equation (16) allows one to verify that

$$G_3 = \frac{1}{6}\left[G_1 - \frac{1}{2} G_2 \right] \quad (19)$$

It is always possible to find a pair of solutions such that one behaves well at zero and the other at ∞. In problems involving Kummer's equation this is usually accomplished by selecting a solution based upon ${}_1F_1(\alpha,\gamma,x)$ (well behaved at $x = 0$) and by selecting one based upon $U(\alpha,\gamma,x)$ (well behaved at $x = \infty$). For informational purposes the limiting form of these solutions in the region of interest follow (Jeffreys and Jeffreys, 1950).

$$r \sim 0 \quad {}_1F_1(\alpha,\gamma,x) = 1 + \frac{\alpha}{\gamma}x + O(x^2)$$

$$r \sim \infty \quad U(\alpha,\gamma,x) \sim x^{-\alpha}\left(1 + \frac{\alpha(\gamma-\alpha-1)}{x} + O\left(\frac{1}{x^2}\right)\right)$$

The Whittaker Solutions.—A similar treatment to that just given can be made for solutions based upon Whittaker's standard form. The solutions are called Whittaker functions. For example, after comparing Equations (11) and (12) to obtain the values of k and m, one can write

$$w_1 = M_{1,3/2}(z)$$

$$w_2 = M_{1,-3/2}(z)$$

$$w_3 = W_{1,3/2}(z)$$

$$w_4 = W_{-1,3/2}(-z)$$

The solution for w_3 is given by the integral representation (Whittaker and Watson, 1952).

$$W_{k,m}(z) = \frac{e^{-\frac{1}{2}z}z^k}{\Gamma\left(\frac{1}{2} - k + m\right)} \int_0^\infty t^{-k-\frac{1}{2}+m}(1+t/z)^{k-\frac{1}{2}+m}e^{-t}dt$$

The result, for the current problem, is

$$w_3 = e^{-\frac{1}{2}z}\, z\left[1 + \frac{2}{z} + \frac{2}{z^2}\right]$$

which leads directly to the G_2 given by Equation (17).

The solution, for w_4 is found from the asymptotic expansion (Whittaker and Watson, 1952).

$$W_{-k,m}(-z) \sim (-z)^{-k}e^{\frac{1}{2}z}\left[1 - \frac{m^2 - (k+\frac{1}{2})^2}{1!z} + \ldots\right]$$

For the current problem this series terminates, giving

$$w_4 = -\frac{1}{z}e^{\frac{1}{2}z}$$

which leads directly to G_1 given by Equation (16). The difference in sign does not alter any of the properties discussed in succeeding sections so long as the sign usage is consistent.

Another set of four functions are obtained by replacing k by $-k$ and z by $-z$. Some books Whittaker and Watson, 1952, and Buchholz, 1953) base their entire treatment on Whittaker functions, while others, e.g. Slater (1960), use both treatments. The latter volume gives the pertinent interrelations. With either treatment, one arrives at the same solutions to the homogeneous equation, (Slater, 1960).

The preceding material has been given in detail, since differential equations whose solutions are confluent hypergeometric functions occur frequently in radial quantum mechanical problems. The texts referred to provide excellent starting points for the reader in obtaining solutions to a particular problem.

Variation of Constants

One method for the solution of an inhomogeneous differential equation is the variation of constants (Burington and Torrance, 1939, p. 361 et. seq.). Basically, the idea for a second order linear differential equation is to first write the equation such that the coefficient of the second derivative is unity, e.g.

$$g''(r) + \left(\frac{2}{r} - 2\right)g'(r) - \frac{2}{r^2}g(r) = -2\mathcal{E}r \qquad (20)$$

The general solution of the homogeneous equation (Slater, 1960) associated with Equation (20) is a linea · combination of two linearly indepcndent solutions of Equation (5). Such a solution is called the *complementary function.* To obtain the general solution of Equation (20), a *particular integral* must be added to the complementary function.

The particular integral is assumed to be a sum of two independent solutions of the homogeneous equation. However, the combining coefficients are themselves functions of the dependent variable. The analogy to the homogeneous solution as a linear combination (but with constant coefficients) of solutions gives rise to the contradiction in terms which entitle this section.

To illustrate the method, the solutions given by Equations (16) and (17) are used. The particular integral is

$$P(G_1,G_2) = C_1(z)G_1 + C_2(z)G_2 \qquad (21)$$

where

$$C_1(z) = -\int \frac{G_2 I}{W}\,dz$$

$$C_2(z) = \int \frac{G_1 I}{W}\,dz$$

$$W(G_1,G_2) = G_1G_2' - G_1'G_2$$

and I is the inhomogeneity of Equation (20). (For other than second order equations, Burington and Torrance (1939) suggests a general method). For the sake of notational simplicity, the use of the variable z is maintained.

For this problem, one finds

$$W(G_1,G_2) = -\frac{4\zeta^2 e^z}{z^2}$$

$$C_1(z) = \frac{e^{-z}}{\zeta^4}\left[\frac{z^3}{8} + \frac{5z^2}{8} + \frac{3z}{2} + \frac{3}{2}\right]$$

$$C_2(z) = \frac{z^2}{16\zeta^4}$$

$$P = \frac{1}{\zeta^3}\left[\frac{z^2}{8} + \frac{z}{2} + \frac{3}{2} + \frac{3}{z} + \frac{3}{z^2}\right]$$

Then

$$g = c_1\left[\frac{2\zeta e^z}{z^2}\right] + c_2 2\zeta\left[1 + \frac{2}{z} + \frac{2}{z^2}\right] + \frac{1}{\zeta^3}\left[\frac{z^2}{8} + \frac{z}{2} + \frac{3}{2} + \frac{3}{z} + \frac{3}{z^2}\right]$$

Since this is not a purely mathematical exercise, one must also ask about the boundary conditions. In particular, the solution for Ψ^1 (Equation (2)) must be finite at both r = O and r = ∞. This will not be true for r = O unless, in the radial function g, c_1 = O and $c_2 = -3/4\zeta^4$. The decreasing exponential in Ψ° is not sufficient to "kill" the e^z term at r = ∞, but having already chosen c_1 = O, this problem is of no import. Using these values for c_1 and c_2

$$g = \frac{1}{\zeta^3}\left[\frac{z^2}{8} + \frac{z}{2}\right]$$

It should also be pointed out that one will obtain the same solution, Equation (22) if one starts with another pair of solutions of the homogeneous equation (5). For example, if instead of Equation (21) one takes

$$P(G_3,G_2) = C_3(z)G_3 + C_4(z)G_2$$

where G_3 is given by Equation (19), then it can be shown by substitution that

$$W_1(G_3,G_2) = G_3G_2' - G_3'G_2 = \frac{1}{6}W(G_1,G_2)$$

$$C_3(z) = 6C_1(z)$$

$$C_4(z) = C_2(z) + \frac{1}{2}C_1(z)$$

$$P(G_3,G_2) = P(G_1,G_2)$$

Thus, one obtains the same particular integral as before. Although the complementary function is different, the linear constants must again be chosen so as to fit the boundary conditions. Once this is done, one again obtains Equation (22).

Green's Function

The Green's function method (Sagan, 1961) is similar to the method of variation of constants described in the preceding section. This method has particular appeal to physicists while the variation of constants is usually described in books by mathematicians. As will be seen, the principal difference lies in the point of insertion of the boundary conditions. In the method just described, one applied the boundary conditions to the general solution in order to determine the two integration constants. In using the Green's function, the boundary conditions are taken in account during formulation of the problem.

The first step in this method is to write the differential equation in *self-adjoint* form (Sagan, 1961). That is, the equation must be of the form

$$\left\{ \frac{d}{dx}\left[p(x)\frac{d}{dx} \right] + q(x) \right\} y = -I(x) \qquad (23)$$

Equation (3) cannot be put into this form directly; but after making the substitutions, given in Equation (8) and $z = 2\zeta r$, and rearranging, one obtains (corresponding to the homogeneous Equation (11))

$$w'' + w\left[-\frac{1}{4} + \frac{1}{z} - \frac{2}{z^2} \right] = -\frac{z^2}{8\zeta^4} e^{-\frac{1}{2}z}$$

or

$$\left\{ \frac{d}{dz}\left[1\frac{d}{dz} \right] + \left[-\frac{1}{4} + \frac{1}{z} - \frac{2}{z^2} \right] \right\} w = -\frac{z^2 e^{-\frac{1}{2}z}}{8\zeta^4} \qquad (24)$$

which is in the self-adjoint form with

$$P(z) = 1$$

$$q(z) = -\frac{1}{4} + \frac{1}{z} - \frac{2}{z^2}$$

$$I(z) = \frac{z^2 e^{-\frac{1}{2}z}}{8\zeta^4}$$

The Green's function $G(x, \xi)$ for the standard form, Equation (23), is

$$G(x,\xi) = \begin{cases} -\dfrac{y_1(x)y_2(\xi)}{P(\xi)W[y_1y_2]} & x < \xi \\ -\dfrac{y_1(\xi)y_2(x)}{P(\xi)W[y_1,y_2]} & \xi \leq x \end{cases}$$

where $y_1(x)$ and $y_2(x)$ are two linearly independent solutions of the corresponding homogeneous equation of Equation (23) in the regions, $x < \xi$ and $\xi \leq x$, respectively; $W[y_1,y_2]$ is the Wronskian, $y_1(\xi)y'_2(\xi) - y'_1(\xi)y_2(\xi)$; and ξ is a dummy integration variable. Then the solution of the inhomogeneous Equation (23) is given (Sagan, 1961) by

$$y(x) = \int_a^b G(x,\xi)\, I(\xi)\, d\xi$$

where a and b are the end points of the region specified by the boundary conditions.

Since the homogeneous equation associated with Equation (24) is just Equation (11), the solutions $y_1(z)$ and $y_2(z)$ are simply Whittaker functions. However, one must be careful to use those functions which behave properly in the appropriate ranges of integration.

As was shown in Section c, two immediate solutions of Equation (11) are

$$w_3(z) = W_{1,3/2}(z) = e^{-\frac{1}{2}z}z\left[1 + \frac{2}{z} + \frac{2}{z^2} \right]$$

$$w_4(z) = W_{-1,3/2}(-z) = -\frac{e^{\frac{1}{2}z}}{z}$$

corresponding to the solutions obtained in Equations (17) and (16), respectively. However, this pair of solutions is not suitable since $W_{-1,3/2}(-z)$ does not behave well at either $r = 0$ or $r = \infty$. Therefore, it is necessary to find the proper linear combination which will behave correctly at $r = 0$ (since in this case, $W_{1,3/2}(z)$ behaves well at $r = \infty$). As is easily verified, by ex-

panding the exponentials, the proper combination is

$$w_5(z) = \frac{1}{2}W_{1,3/2}(z) + W_{-1,3/2}(-z) = \frac{1}{2}w_3 + w_4$$

$$w_3(z) = W_{1,3/2}(z)$$

Except for a numerical factor, which does not affect the problem, the solution $W_5(z)$ corresponds to the combination in Equation (19).

For the present problem, the solution of Equation (24) in these terms is

$$w(z) = -w_3(z)\int_0^{\xi} \frac{w_5(\xi)I(\xi)}{P(\xi)W[w_5,w_3]}\,d\xi - w_5(z)\int_{\xi}^{\infty} \frac{w_3(\xi)I(\xi)}{P(\xi)W[w_5,w_3]}\,d\xi \qquad (25)$$

Although this example leads to an easily derived Wronskian, it should be pointed out that Slater (1960) tabulates Wronskians for various pairs of Kummer functions and for various pairs of Whittaker functions. For this problem

$$W[w_5,w_3] = 1$$

$$I = \frac{z^2e^{-\frac{1}{2}z}}{8\zeta^4}$$

$$P(\xi) = 1$$

The two integrals are

$$\int_0^z \left[\frac{e^{-\frac{1}{2}\xi}}{2}(\xi + 2 + \frac{2}{\xi}) - \frac{e^{-\frac{1}{2}\xi}}{\xi}\right]\left[\frac{\xi^2e^{-\frac{1}{2}\xi}}{8\xi^4}\right]d\xi$$

$$= -\frac{1}{16\zeta^4}[z^2 + e^{-z}(z^3 + 5z^2 + 12z + 12) - 12] \qquad (26a)$$

$$\int_z^{\infty} \left[e^{-\frac{1}{2}\xi}\quad(\xi + 2 + \frac{2}{\xi})\right]\left[\frac{\xi^2e^{-\frac{1}{2}\xi}}{8\zeta^4}\right]d\xi$$

$$= \frac{1}{8\zeta^4}\left[e^{-z}(z^3 + 5z^2 + 12z + 12)\right] \qquad (26b)$$

Substituting Equations (26) into Equation (25) gives

$$W(z) = \frac{e^{-\frac{1}{2}z}}{8\zeta^4}\left[\frac{z^3}{2} + 2z^2\right]$$

and applying the inverse of the transformation of Equation (8) [in terms of the new variable $z = 2\zeta r$], once again one obtains

$$g = \frac{1}{\zeta^3}\left[\frac{z^2}{8} + \frac{z}{2}\right] \qquad (22)$$

Method of Undetermined Coefficients

There exists still another method of finding a particular integral, the method of assuming a series solution (Ince, 1944) and determining the unknown coefficients of the individual terms in the series. Clearly, in a problem such as the one under discussion, the series will terminate after a finite number of terms.

In order to solve Equation (3), a series solution in z is assumed (after the appropriate transformation to the new variable $z = 2\zeta r$). However, this corresponds to an expansion in a Taylor series about zero which normally implies that one has to worry about whether the point of expansion (zero in this example) is an *ordinary point* or a *singular point* (Ince, 1944). Since in this problem the series is finite, no question of convergence arises and there is no need to worry about the fact that $z = 0$ is really a singular point of Equation (3).

Transforming Equation (3) to an equation in the variable z gives

$$g''(z) + \left(\frac{2}{z} - 1\right)g'(z) - \frac{2}{z^2}g(z) = -\frac{z}{4\zeta^3} \qquad (27)$$

The assumed solution is

$$P = Az^3 + Bz^2 + Cz + D \qquad (28)$$

This assumption is reasonable since it contains the information that the particular integral is a finite polynomial and further, after two differentiations, the highest power of z is the highest power in the inhomogeneity.

Substituting Equation (28) into Equation (27) and equating the coefficients of like powers of z leads to the following system of equations

$$\begin{aligned} -3A &= 0 \\ 10A - 2B &= -\frac{1}{4\zeta^3} \\ 4B - C &= 0 \\ -2D &= 0 \end{aligned}$$

whose solution is

$$\begin{aligned} A &= 0 \\ B &= \frac{1}{8\zeta^3} \\ C &= \frac{1}{2\zeta^3} \\ D &= 0 \end{aligned}$$

Therefore, substituting these coefficients in Equation (28), yields

$$P = \frac{1}{\zeta^3}\left[\frac{z^2}{8} + \frac{z}{2}\right]$$

Once again it is necessary to obtain a complete solution by adding a complementary function and evaluating the constants of integration. Then, constructing the complementary function from Equations (17) and (19), for example, one obtains

$$g = c_1G_2 + c_2G_3 + \frac{1}{\zeta^3}\left[\frac{z^2}{8} + \frac{z}{2}\right]$$

Since g must behave properly at $r = 0$ and $r = \infty$, then $c_1 = c_2 = 0$. The solution for g is that previously found

$$g = \frac{1}{\zeta^3}\left[\frac{z^2}{8} + \frac{z}{2}\right]$$

Summary

Three methods of finding a particular integral have been demonstrated and some comments have been made concerning their differences. Since the final answer is the same, the choice between methods usually lies in which method entails the least effort.

Unlike the other methods, the method of undetermined coefficients does not demand knowledge of solutions to the homogeneous equation. If one is fortunate enough to have a problem whose solution is a finite polynomial or an easily recognizable series, this method avoids the work of obtaining complementary functions which are of no practical interest.

A comparison is made of the two sets of solutions arising from the different standard forms of differential equations whose solutions are confluent hypergeometric functions. Facility in the use of confluent hypergeometric functions is a great aid in solving many of the radial problems arising in quantum mechanics. This is particularly true in those cases where the method of undetermined coefficients provides an inconsistent set of algebraic equations and it is necessary to obtain the complementary function. Finally, it should be noted that in many cases the confluent hypergeometric solutions are infinite series which

will be inconvenient in determining the particular integral, but the methods are still valid.

Acknowledgment

This research was supported by the National Aeronautics and Space Administration Grant NsG-275-62 (4180) while the author was on leave (1963-4) from Southern Illinois University, Carbondale, Illinois. The encouraging assistance of Prof. Saul T. Epstein whose probing questions led to the comparisons made in this report are gratefully acknowledged. Thanks are also accorded to Prof. W. Byers Brown for helpful discussions during the development of this formalization.

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Manuscript received May 6, 1965.

NEWS AND COMMENTS

This issue marks the end of an "experiment." Your editor made an effort to have 100 or more pages in each issue. To get 100 printed pages it is necessary to have 200 to 250 manuscript pages and some figures. Believe me, seeing that material through all the steps to a complete issue every three months turned out to be a bit more work than I had anticipated. The large number of errors, discrepancies in format, and, obviously, less critical editing show that even more work than I was able to give should have gone into the volume. On the other hand, I am glad I did it—once. Some objective figures were obtained on the amount of time needed for each issue.

This is as good a time as any to announce one more break with our "traditional format." Authors may add departmental, or other divisional designations, to their institutional addresses. I yet reserve the "right" to keep these things within the bounds of reasonableness.

May I ask for another favor from authors? I would appreciate a letter of transmittal that would accompany a paper. I would be pleased if that letter would state the exact title, name of the author or authors, number of pages in the text, number of figures, and number of tables. Lastly, I would appreciate receiving what the letter says I am to get. This paragraph is prompted by a mix-up or a practical joke—I know not which.

Now is the time to admit that I am not keeping my end of the bargain. Acknowledgments of receipt of manuscripts have been slow or nonexistent on my part lately. Mind you, I'm only confessing my neglect. I am not promising to do better.

Kenneth E. Damann, after nineteen years at Eastern Illinois University, is leaving the State of Illinois for SUNY. Professor Damann writes, "This abbreviation represents State University of New York. We will be located at the State University College of Brockport, which is only eighteen miles northwest of Rochester and less than ten miles from Lake Ontario. It should probably be called SNOWY as the average snowfall is 82 inches". In July, 82 inches of snow impresses me.

Professor Damann will be Head of a newly created Biological Science Department. I must admit that Professor Damann listed a few of the wonderful advantages at Brockport, but they sounded too good to be true so I shan't repeat them.

More News from Eastern: Dr. G. Husa has been named acting head of the Department of Botany. Dr. Husa comes to Eastern Illinois University from Northern Illinois University where he taught botany and biology. He received his B.S. in Ed. from Northern in 1953, and an M.S. in Ed. in 1956. His Ph.D. was completed at the University of Chicago in 1964. Teaching experience includes five years of junior high

school and two years at Chicago Teachers College South before going to Northern.

The Illinois State Museum was the recipient of a National Science Foundation Grant of $35,600 for archaeological and metallurgical research in Iran. Dr. Joseph R. Caldwell is the principal scientist in charge of the expedition which assembled in Tehran, Iran on September 1, 1966 to engage in surveys and excavations for approximately two months. Some of the group are working at the prehistoric site of Tal-i-Iblis, near Kerman, where in 1963 Dr. Caldwell found evidence of the smelting of copper as early as 4,000 B.C., for the purpose of obtaining further evidence of this early smelting and related cultural developments. At the same time, the metallurgists in the group are conducting a general survey of the sources of copper ores which may have been available to these early people.

The Illinois State Museum recently published under the Museum's *Preliminary Reports, No. 7,* the report "TAL-i-IBLIS, The Kerman Range and the Beginnings of Smelting." The report is in English and Persian, prepared by Dr. Joseph R. Caldwell and Sadegh Malek Shahmirzadi and is available for $1.50 at the Illinois State Museum.

Illinois State Academy of Science Receives NSF Grant for Visiting Lecturer Program

The Illinois State Academy of Science has received a grant of $9,520 from the National Science Foundation to conduct a program of visiting lecturers for the high schools of Illinois to be carried on during the 1966-67 school year. A similar program was conducted during the 1965-66 school year, and ninety-one (91) high schools participated in the program. The budget for the 1966-67 program will permit approximately one hundred twenty-five (125) visits. This project is under the direction of Dr. Frederick W. Rolf, Professor Chemistry at Northern Illinois University in DeKalb.

The major purpose of the project is to motivate talented high school students to pursue careers in science and mathematics with the hope that some of these students may be inspired to prepare themselves for careers as high school science and mathematics teachers.

Every high school principal and every high school teacher of science or mathematics in Illinois will be informed of this program and will be encouraged to apply for one of these visits. Visiting lecturers will be available in the fields of Biology, Chemistry, Earth Science, Mathematics, and Physics. Each school which applies for a visitor will designate the specific area of science of mathematics in which a visiting lecturer is needed.

Members of the Illinois State Academy of Science, professors of science and mathematics from colleges and universities throughout the State, and industrial scientists and mathematicians will be informed of this program and given an opportunity to participate in it as visiting lecturers. All prospective visiting lecturers will be asked to indicate the subject area and the specific topics they wish to discuss during a visit to a high school.

Every effort will be made to match the requests of the high school with the interests of the visiting lecturer so that each visit can be "tailor made" for the school. Travel will be kept at a minimum so overnight trips will be virtually eliminated. The budget of the program calls for a $40.00 honorarium for a full day of visitation plus 8 cents per mile for travel in a private car plus the cost of meals purchased during the period of the trip.

It is probable that the Visiting Lecturer Program will be a continuing activity of the Illinois State Academy of Science for years to come. As the program expands and is perfected, it could well become one of the major continuing projects of the organization. It offers a unique opportunity for the Illinois State Academy of Science to create and strengthen a bond of association between the high school science and mathematics teachers of the State and their colleagues in the colleges and universities of Illinois. We were off to a good start in 1965-66. With an increased budget for 1966-67, even more should be accomplished in the coming school year.

Members of the Illinois State Academy of Science who are interested in participating in this project are invited to contact Dr. F. W. Rolf at Northern Illinois University.

NOTES

SCALE OF ILLUSTRATIONS OF ILLINOIS HALORAGACEAE

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ABSTRACT. — In "The Illinois Species of Haloragaceae and Hippuridaceae" (Meyer and Mohlenbrock, Trans. Illinois Acad. Sci. 59:149-162) the scale of each illustration is X25 for the fruit and X1 for the plant.

In "The Illinois Species of Haloragaceae and Hippuridaceae" by Meyer and Mohlenbrock, which appeared in the second issue of volume 59 of the Transactions, the scale for the seven illustrations was inadvertently omitted.

The fruit in each illustration is X25, while the plant sketch is X1 for each species.

The co-authorship for this erratum is the result of the equal feeling of guilt on the part of the junior author of the article and the editor.

Manuscript received June 28, 1966.

A NEW FORM OF *HOUSTONIA PUSILLA* FROM ILLINOIS

R. P. WUNDERLIN and W. E. HOPKINS
Southern Illinois University

ABSTRACT.—*Houstonia pusilla* Schoepf forma *albiflora* Wunderlin et Hopkins, new to science, is described.

A white-flowered form of *Houstonia pusilla* Schoepf was discovered in Split Rock Hollow, Johnson County, Illinois by the authors. The white-flowered form is locally abundant on open sandstone ledges in pure colonies and with the typical blue-flowered form. The two forms are quite distinct, the typical form being deep blue with a dark eye and the other pure white with a yellow eye. Since white-flowered forms have been recognized in this genus, it is keeping with consistency to record the following previously undescribed form:

Houstonia Pusilla Schoepf forma Albiflora Wunderlin et Hopkins, forma nova

A varietate *pusilla* recedit floribus albidis. JOHNSON CO.: Split Rock Hollow, April 8, 1966, R. P. Wunderlin and W. E. Hopkins 1. (HOLOTYPE and ISOTYPE in Southern Illinois University Herbarium).

Manuscript received May 23, 1966.

SOME *LIATRIS* NEW TO ILLINOIS

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ABSTRACT. — *Liatris ligulistylis*, *Liatris aspera* forma *benkii*, and *Liatris spicata* forma *albiflora* are reported as occurring in Illinois for the first time.

Recent investigations of specimens of the genus *Liatris* in the herbaria of Southern Illinois University and the Illinois State Museum have led to the discovery of the following species and forms previously unrecorded for Illinois:

Liatris ligulistylis (Nels.) K. Schum.

Liatris ligulistylis resembles *Liatris aspera* from which it differs by having ciliate leaves and phyllaries, the corolla-tubes essentially glabrous within, and the pappus 8-10 mm long. *Liatris aspera* has eciliate leaves, erose and eciliate phyllaries, the corolla-tube pilose within, and the pappus 7-8 mm long.

The following collection is deposited in the herbarium at the Illinois State Museum:

COOK CO.: Orland Park, Sept. 11, 1943, *G. Pearsall 8332*.

Liatris aspera Michx. forma benkii (Macbr.) Fern.

Liatris aspera forma *benkii* differs from the typical *Liatris aspera* by having the flowers white in color rather than rose-purple.

The following collections are deposited in the herbarium at the Illinois State Museum:

CASS CO.: Sept. 10, 1959, *R. T. Rexroat 6318*. COOK CO.: Dalton, Sept. 4, 1943, *G. D. Fuller 8154*. LAKE CO.: Sept. 3, 1949, *G. D. FULLER 14548*.

Liatris spicata (L.) Willd. forma albiflora Britt.

Liatris spicata forma *albiflora* differs from the typical *Liatris spicata* by having the flowers white in color rather than rose-purple.

The following collection is deposited in the herbarium at Southern Illinois University:

POPE CO.: Belle Smith Springs, July 12, 1951, *J. L. Landolt s.n.*

Manuscript received July 14, 1966.

PRODUCTION OF INDOLEACETIC ACID BY *CEPHALIOPHORA TROPICA*

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Southern Illinois University, Carbondale

ABSTRACT. — Mycelium of *Cephaliophora tropica* produced indoleacetic acid (IAA) in liquid medium when grown in either continuous light or dark. Fresh weight of light-grown mycelium was about twice that of the dark-grown mycelium, while dry matter produced in both treatments was about the same. Medium of dark-grown mycelium contained more IAA than that of light-grown.

Many fungi are known to produce indoleacetic acid (IAA) (Gruen, 1959), and inhibition of their growth by this substance is common (Cochrane, 1958). Some fungi produce IAA in the absence of an added precursor in the medium (Ulrich, 1960) although IAA synthesis usually requires the addition of tryptopthan or a metabolically related compound (Bailey and Gentile, 1962; Brian, 1957; Mace, 1965; Thimann, 1935; and Wolf, 1952). Gentile and Klein (1955) suggested that *Diplodia natalensis* Pole-Evans synthesized IAA in medium with or without tryptophan indicating the possibility that this fungus was autotrophic for this substance. They reported that IAA in the growth medium could reach inhibitory levels through this synthetic activity. Bailey and Gentile (1962) separated and identified several indole compounds synthesized by *D. natalensis*. Using C^{14}-labeled tryptophan they demonstrated that tryptophan proceeded to indoleacetic acid, indolelactic acid, and tryptophol. The fungus also converted tryptamine to indoleacetic acid.

Weik and Pappelis (1964) demonstrated that *Cephaliophora tropica* Thaxter grew well on many nitrogen sources but poorly in a medium with tryptophan as the nitrogen source. Since tryptophan normally is considered to be a poor source of nitrogen for fungi (Cochrane, 1958) it was hypothesized that *C. tropica* may be autotrophic for IAA and that the addition of tryptophan to the growth medium may be permitting the fungus to convert this to inhibitory levels of IAA. This paper presents data on a study of the production of IAA by *C. tropica* grown in continuous light or dark.

MATERIALS AND METHODS

A small piece of *Cephaliophora tropica* obtained from the leading edge of a colony growing on potato dextrose agar was grown in the dark in 50 ml of autoclave-sterilized Czapek-Dox broth medium (Fisher Scientific) containing 0.5 g of Yeast Extract (Baltimore Biological Laboratories) per liter on a rotary shaker at 110 rpm in 125 ml Erlenmeyer flasks. The colony was isolated, washed, and macerated at high speed as described by Weik and Pappelis (1964). One ml of the macerated mycelium was used to inoculate additional flasks containing 50 ml of sterile Czapek-Dox broth medium containing 0.5 g of BBL Yeast Extract and 0.5 g of vitamin free casamino acids (Difco Laboratories) per liter. Flasks were divided into two groups. Flasks of one group were wrapped with aluminum foil to cover all except the cotton plug. The cotton plug was covered with a 5 inch square of foil and the four corners pushed downward to make a loose cap. The second group was covered only with the aluminum caps. Both groups were placed on a rotary shaker illuminated (300 foot-candles) with Gro-Lux fluorescent tubes (Pappelis, Schmid and Koike, 1964) and agitated for 4 days at 110 rpm. At the end of the growth period, the mycelia from 5 flasks were harvested, washed quickly with distilled water, and collected with a Buchner funnel on a filtering flask using a uniform 40 psi water pressure provided by a Buchler Water-

Booster pump (aspiration for a three minute interval). The mycelial pads were weighed, dried at 70°C for 24 hours, cooled in a desiccator and reweighed.

The culture filtrates were collected and extracted for IAA according to the methods described by Sequeira and Kelman (1962). The concentrated material was chromatogramed with isopropanol-ammonium hydroxide-water (10:1:1), *n*-butanol-ammonium hydroxide-water (100:3:18), and *n*-butanol-ethanol-water (4:1:1). IAA was detected on paper using U.V. fluorescence and color reaction with the modified Salkowski reagent (Gordon and Weber, 1951).

Results and Discussion

The growth of *C. tropica* in light and dark differed in that the fresh weight of mycelium grown in continuous light was 2.12 g total in the five flasks while that for mycelium grown in the dark was 1.03 g. The mycelial dry matter produced in the light was 0.47 g total in the five flasks, and 0.43 g of dry matter was produced in the dark. These differences in dry weights were not considered to be significant. The mycelium in the light and dark treatments appeared similar in color and texture, and no significant viscosity differences in growth media were detected.

The presence of IAA in the culture filtrate was indicated chromatographically by comparison with known IAA in three different solvent systems. The chromogenic spray reaction with the modified Salkowski reagent was more sensitive in detecting the presence of IAA than U.V. fluorescence. More IAA was present in filtrates of dark-grown mycelium. Thus, mycelia of *C. tropica* grown in the light had twice the fresh weight, the same dry weight, and a decreased amount of IAA as compared to that of mycelia grown in the dark.

Whether light affected the synthesis or destruction of IAA was no determined. Since enzymic IAA oxidation often has been shown to be light-dependent (Hare, 1964), the lower amount of IAA in light-grown filtrates could be explained if the fungus produces an IAA oxidase.

Acknowledgments

This study was supported in part by funds provided by National Science Foundation Grant GB-1072.

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Manuscript received July 14, 1966.

EFFECTS OF FLOODING ON THE MOUSE *PEROMYSCUS LEUCOPUS*

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ABSTRACT. — Marked individuals of *Peromyscus leucopus* apparently were eliminated in an area inundated by flooding. Re-invasion of the area after flooding was by unmarked individuals.

Layne (1958) has indicated that the white-footed mouse, *Peromyscus leucopus*, is abundant in southern Illinois bottomlands that may be partly or completely flooded at certain times of the year. Other authors, Stickel (1948) for example, also have attested to the large numbers of white-footed mice found in bottomlands. Enders (1930) noted that *P. leucopus* tolerates a greater range of moisture than any other rodent in Ohio; Nicholson (1941) and Wetzel (1958) suggested that the species copes with excessive moisture or standing water by living and nesting in trees; and swimming of white-footed mice has been reported (Teeters, 1954; Sheppe, 1965). Thus, judging from the literature, *P. leucopus* is tolerant of excessively moist conditions.

In 1963-1965, some effects of flooding on a population of white-footed mice in a wooded bottomland two-tenths mile southwest of the Carbondale City Reservoir in Jackson County, Illinois, were observed. In the course of trapping over a period of four months (19,858 trap-nights), from 18 May to 23 September 1963 (Turner and Stains, in manuscript), 90 white-footed mice were marked and released. Of these, 35 were known fatalities, leaving 55 marked mice on the area in September, 1963. None of these marked individuals was recaptured in a later trapping period, which began in June, 1964, and continued until May 1965 (80,622 trap-nights). In the early spring of 1964, prior to resumption of trapping, the study area was inundated. The population of *P. leucopus* in the second period of trapping was much reduced over that found in 1963. Although trapping was more extensive in 1964-65 (on about twice as large an area of bottomland and 60,764 more trap-nights than in 1963), only 93 white-footed mice were taken as compared to 90 in 1963. A small part of the breeding stock (27 mice) may have been eliminated by some snap-trapping, but extensive flooding in the late winter of 1963 and spring of 1964 was the probable agent of reduction.

More direct effects of flooding were observed in the last three weeks of February, 1965. Rain in excess of four inches fell in five days (8-12 February). Although flooding was not so extensive as in the spring of 1964, standing water plus low temperatures that prevailed undoubtedly produced conditions that were adverse for small mammals. Only three of 51 white-footed mice marked previous to 8 February were captured after 12 February; these were obtained in a one-acre cornfield that was wet and muddy, but not under water as was the surrounding woodland. Unmarked mice first appeared in the outer traplines of the bottomland study area on 27 February 1965. Recovery of the population was slow; three unmarked individuals were captured in February, seven in March, and nine in April.

Thus, the white-footed mice either emigrated from the area or were drowned. Apparently they did not escape the flood by climbing. If the mice had emigrated, a few individuals would be expected to return after the flood waters had receded. Except for the three mice that were isolated in the cornfield, unmarked individuals subsequently became established in the area. Therefore, decimation rather than emigration was the probable fate of the population of *P. leucopus* that inhabited the wooded bottomland prior to the flood. Blair (1939) reported that flooding adversely affected

populations of white-footed mice; but, re-invasion from adjacent areas, after the recession of flood waters, was not noted.

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Manuscript received June 3, 1966.

NOTES ON COLORADO RESUPINATE BASIDIOMYCETES

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ABSTRACT. — Fourteen species of resupinate Basidiomycetes are reported for Colorado for the first time.

Collections of fungi that extend their reported North American range are noted here. These collections were made by the author (*AEL*) on August 28, 1964, near Allenspark (Elev. 8500 ft.), on the eastern slopes of the Continental Divide, and on September 2, 1964, near Milner Pass (Elev. 10,800 ft.), on the western slopes. The collections are deposited in the mycological herbarium of Illinois State University (ISU).

Amphinema byssoides (Pers. ex Fr.) J. Erikss.
On decayed conifer, IX.2.1964, *AEL 1397, 1398, 1399, 1400*. This widely distributed species was previously unreported for Colorado.

Athelia bicolor (Peck) Parm.
On decayed conifer, VIII.28.1964, *AEL 1415;* IX.2.1964, *AEL 1416*.

Botryobasidium subcoronatum (Hoehn. & Litsch.) Donk
On decayed conifer, VIII.28.1964, *AEL 1417*. Although this species is widespread, it was previously unreported for Colorado.

Cerinomyces pallidus Martin
On decayed conifer, IX.2.1964, *AEL 1404, 1405*. The collection of this species in Colorado extends its known North American range to the western United States. It has been previously reported from Ontario and Iowa by Martin (1952) and from Wisconsin by the author (1965).

Coniophora olivacea (Fr.) Karst.
On decayed conifer, IX.2.1964, *AEL 1410, 1411*. Although this species is especially widespread in the northwestern United States, it was previously unreported for Colorado.

"Grandinia" farinacea (Pers. ex Fr.) Bourd. & Galz.
On decayed conifer, VIII.28.1964, *AEL 1375*; IX.2.1964, *AEL 1374*.

Hyphoderma tenue (Pat.) Donk
On decayed conifer, IX.2.1964, *AEL 1406, 1407, 1408, 1409*. A widely distributed species that was previously unreported for Colorado.

Hyphodontia pallidula (Bres.) J. Erikss.
On decayed conifer, IX.2.1964, *AEL 1418*.

Paullicorticium pearsonii (Bourd.) J. Erikss.
On decayed conifer, IX.2.1964, *AEL 1395, 1396*. The collection of this species in Colorado extends its known North American range to the western United States. It has been previously reported by the author from Iowa and Massachusetts (1962), Wisconsin (1965), and Quebec, Canada (1966).

Sistotrema brinkmanni (Bres.) J. Erikss.
On decayed conifer, IX.2.1964, *AEL 1384, 1385*. A widespread species that was previously unreported for Colorado.

Sphaerobasidium minutum (J. Erikss.) Oberw.
On decayed conifer, IX.2.1964, *AEL 1386, 1387, 1388, 1389*. In addition to Colorado, the reported North American range now includes Connecticut, Illinois, Massachusetts, Oregon, Wisconsin, and Quebec, Canada (Liberta, 1964, 1965).

Tubulicrinis accedens (Bourd. & Galz.) Donk
On decayed conifer, IX.2.1964, *AEL 1401, 1402, 1403*. Weresub (1953) has reported this species from Iowa, Massachusetts, Oregon, Rhode Island, and the Canadian provinces of British Columbia and Ontario. It is also known for Illinois and Indiana (Liberta, 1964),

Tubulicrinis calothrix (Pat.) Donk

On decayed conifer, VIII.28.1964, *AEL 1376, 1377*; IX.2.1964, *AEL 1378, 1379, 1380, 1381, 1382.*

Tubulicrinis inornata (Jacks. & Rogers in Jacks.) Donk

This species was previously reported only from its type locality of Ontario and from Oregon (Jackson, 1948).

Acknowledgments

The author wishes to extend his thanks to Professor and Mrs. H. M. Fitch for the generous hospitality that made the foray to Colorado possible.

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Manuscript received July 16, 1966.

FLUORESCENT MAILLARD REACTION ARTIFACTS IN PLANT EXTRACTS

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ABSTRACT. — A discussion based on literature references is presented which describes the possible formation of fluorescent artifacts by the Maillard reaction during the usual procedures for extraction and isolation of fluorescent secondary plant substances.

Reactions of the amino group of amino acids with sugars has been of particular interest to the food industry and has been the subject of extensive investigations. This reaction, called among other things the Maillard reaction and non-enzymic browning, has been reviewed (Ellis, 1959; Reynolds, 1963, 1965). However, it has not received much attention by plant physiologists, pathologists, or taxonomists. The purpose of this paper is to indicate the possible importance of the reaction to investigators conducting research involving chromatographic separations of fluorescent substances in plant extracts.

As an example of the possible importance of this reaction, in investigations of chemical factors involved in plant disease resistance, plant tissue is usually extracted with boiling ethanol or sometimes with hot water followed by extraction of the aqueous solution with an organic solvent such as ether. Potassium bisulfide and metabisulfite are frequently added to prevent darkening of the extracts. The extracts are then chromatographed and many of the secondary plant substances are located by their fluorescence under ultraviolet radiation.

In addition to some phenolic compounds and many other UV-fluorescing compounds, fluorescence has also frequently been observed in sugar-amino acid reaction mixtures, but the compound(s) responsible for this property has not been identified. For example, refluxing of solutions (0.1-1M) of D-glucose and glycine resulted in at least 10 fluorescent compounds when examined by paper chromatography (Patton and Chism, 1951). Although most workers would consider this a large number of possible artifacts, glycine is not the best producer of fluorescent compounds; tryptophan, histidine, phenylalanine, threonine, lysine, and glumatic acid were demonstrated to be better (Friedman and Kline, 1950; Shore and Pardee, 1956).

Bisulfite is often used to prevent the loss of phenols during extractions. However, the presence of bisulfite not only retards browning but promotes the accumulation of fluorescent compounds in heated mixtures of amino acids and sugars (Friedman and Kline, 1950; Overby and Frost, 1952; Shore and Pardee, 1956). The formation of these compounds has a pH optimum between 6 and 8 (Shore and Pardee, 1956) and is temperature (Pearce, 1950) and moisture (Pearce, 1949) dependent. Experiments conducted in this laboratory confirm these observations. When a mixture of amino acids and fructose was heated in the presence of bisulfite, a mixture of fluorescent compounds was produced. These synthetic fluorescent compounds were absorbed on cyanide-deactivated carbon and eluted with benzene-methanol-water (3:7:1 v/v) as used in the isolation of a glycoside fraction from corn stalks (Wahlroos and Virtanen, 1959; BeMiller and Pappelis, 1965). They are chromatographically similar to some of the compounds extracted by ether from a pH 2 solution obtained from a water extract of corn stalk tissue on which natural glycosidases have acted (BeMiller and Pappelis, 1965a).

The synthetic compounds obtained from amino acids and fructose do not show reactions with spray reagents similar to those of the phenolic acids; for example, they do not exhibit in-

creased fluorescence when sprayed with 5% sodium carbonate.

It is not known whether or not any of the compounds in corn stalk extracts which are similar chromatographically and by fluorescent reactions to the synthetic compounds are indeed reaction products of amino acids and sugars. Even if they are, it is not known whether they are naturally occurring compounds like the amino acid-chlorogenic acid addition compound (Clark et al., 1959) or artifacts produced during hot water or hot ethanol extraction and subsequent concentration.

From the literature discussed here, however, it appears that the extraction conditions commonly used with plant materials are ideal for artifact formation and it is quite possible that such compounds will be present in these extracts. Since they could become part of various purified fractions, they could interfere with the location of naturally occurring fluorescent compounds. Hence, these compounds formed by the Maillard reaction need further study, especially by plant physiologists, pathologists, and taxonomists conducting chromatographic separations or similar studies of fluorescent substances in plant extracts.

Acknowledgment

The author acknowledges the financial support given this work by the National Science Foundation under grant GB-1072.

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Manuscript received July 23, 1966.

LOPHOTRICHUS BREVIROSTRATUS, A FUNGAL SPECIES NEW TO ILLINOIS

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ABSTRACT. — *Lophotrichus brevirostratus* Ames, not previously reported from Illinois, was found as a contaminant in a bacterial plate at Southern Illinois University, Alton.

The genus *Lophotrichus* Benjamin (1949) (Chaetomiaceae, Ascomycetes) contains at present three recognized species: *L. ampullus* and *L. martini*, both described by Benjamin, and *L. brevirostratus* Ames (1961, p. 52). According to Ames, *L. ampullus* is known from Illinois, Kansas, Virginia, and Michigan but *L. martini* is known only from Talara, Peru. The type locality of *L. brevirostratus* is Edwards County, Kansas; this is the first report of its occurrence anywhere else. Whiteside (1962) has studied the morphology of *L. ampullus* and *L. martini*, and Bulat (1950) has determined that both of these species are cellulose-decomposing. To the best of our knowledge, the literature on *L. brevirostratus* consists only of the original description (Ames, 1961, p. 52).

Felix A. Tornabene found *Lophotrichus brevirostratus* Ames contaminating a bacterial plate in a laboratory of Southern Illinois University, Alton. The bacterial medium is an unusual substrate for *Lophotrichus* which ordinarily occurs in dung. The two species studied by Bulat (1950) were litter-inhabiting and not primarily coprophilous.

Hyphal segments from the bacterial plate were transferred to another plate containing corn meal agar and a pure culture was established. The highly characteristic perithecia (Fig. 1) became macroscopically visible 9-10 days after inoculation; they reached their maximum size (approx. 210 x 225μ) and released their ascospores en masse after 10 more days. As far as we are able to determine, this fungus differed from the type as described by Ames (1961, p. 52) only in having somewhat smaller perithecia and shorter terminal hairs.

There are now two *Lophotrichus* species known from Illinois: *L. ampullus* and *L. brevirostratus*. Whiteside (personal communication) has isolated a *Lophotrichus* in the Charleston, Illinois area which he has not yet identified to species. It will be interesting to know what species he has.

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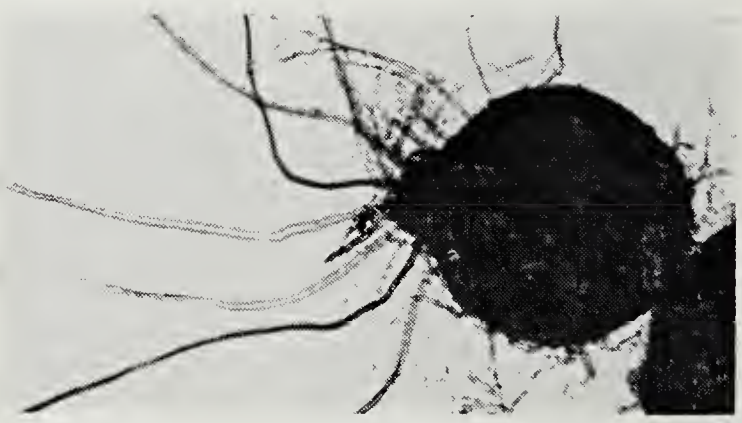

FIGURE 1. — A mature perithecium of *Lophotrichus brevirostratus* Ames, (180 x 200 μ). Terminal hairs (380 — 570 μ long) are finely septate and straight.

A COLLECTION OF MADTOM CATFISH, *NOTURUS FUNEBRIS*, FROM WESTERN FLORIDA

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ABSTRACT. — Length-frequency, sex ratio, associated fishes, and observations on sexual maturity are given for an unusually large sample of the black madtom, *Noturus funebris*.

The black madtom, *Noturus funebris* Gilbert and Swain, is a secretive ictalurid catfish living in small coastal streams from Louisiana to Florida. This species is seldom collected in large numbers and little is known of its life history. A collection of 429 individuals was made by Florida Game and Freshwater Fish Commission workers and given to the Tulane University Ichthyological Collections. This collection was made using 1.5 quarts Rotenone, 8 March, 1961, Metts Creek, Yellow River drainage, Okaloosa Co., Florida. Total fishes collected were: 2 *Ichthyomyzon gagei*, 19 *Esox americanus*, 2 *E. niger*, 7 *Erimyzon tenuis*, 56 *Notropis hypselopterus*, 144 *N. signipinnis*, 50 *N. texanus*, 6 *Ictalurus natalis*, 429 *Notorus funebris*, 81 *N. leptacanthus*, 15 *Aphredoderus sayanus*, 3 *Fundulus notti*, 5 *Ambloplites rupestris*, 1 *Chaenobryttus gulosus*, 1 *Lepomis marginatus*, 100 *L. punctatus*, 2 *Micropterus salmoides*, 10 *Percina nigrofasciata*, and 1 *Etheostoma edwini*.

Standard length (SL) of the 429 *N. funebris* were measured to the nearest millimeter with dial calipers. The body cavity was opened and sex determined by gross examination of the gonads. As is usual in madtoms, no external sexual differences were discernible, but even in the smallest individual examined (21 mm SL) sex was easily determined by examination of the gonads. An attempt was made to study age and growth using annuli of the pectoral spine. The procedures used were those of Leonard and Sneed (1951) as modified by Clugston and Cooper (1960). This attempt was unsuccessful because long preservation in formalin had caused the spines to crack and the annuli were obscured and could not be used as age markers.

Length-frequency relations are shown in FIGURE 1. The first peak from 25 to 35 mm SL, may represent year class I, fish hatched in the summer of 1960 and thus less than a year old. This size range is probably not adequately repre-

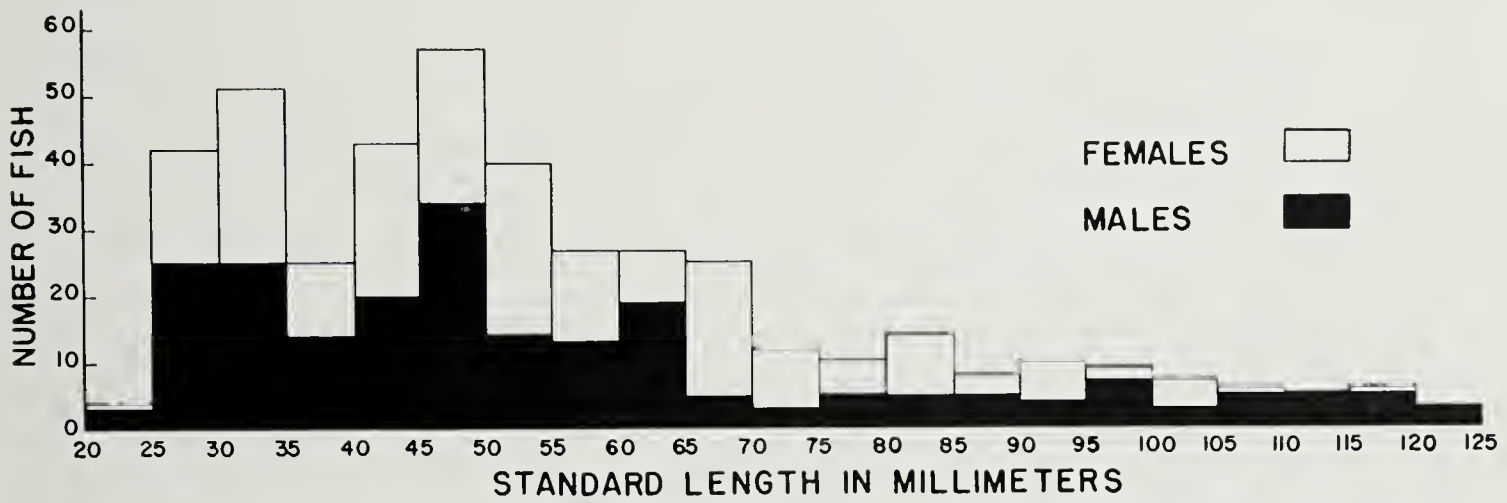

FIGURE 1. — Length-frequency diagram for 429 specimens of *Noturus funebris* collected in the Yellow River drainage (Metts Creek) of Western Florida on March 8, 1961.

sented because small individuals are less likely to be recovered by collectors using poison than are larger fish of the same species. The second peak at 45-50 mm SL is thought to correspond to year class II, hatched in the summer of 1959. The third peak, at 55 to 65 mm SL, is less distinct than the first two and probably represents individuals hatched in the summer of 1958 and thus belonging to year class III. Larger individuals are probably older but this is not demonstrable from these data. Sex ratio for the sample was 221♂ to 208♀. The predominance of males in the size classes above 95 mm SL suggests that males may attain a larger size than females or that large females may have a higher mortality rate than large males.

Gross examination of testes of these preserved males did not allow discrimination between mature and immature individuals. The male gonads may not have been active at the time the collection was made, but three of the largest females (103,106, and 119 mm SL) had ovaries containing large (2-3mm) yolked ova. The other 205 females in the Metts Creek sample had ova smaller than 1.5 mm diameter. Examination of 28 other females (58 to 104 mm SL) available in other Tulane University collections revealed 2 additional ripe females. The larger (104 mm SL) had normal ovaries but the smaller (91 mm SL) had asymmetrically developed ovaries, the left being about 3 times as large as the right. The total volume of her ovaries was the same as in a normal female. All other females of *N. funebris* seen by me have had equal development of both ovaries. Although not enough females were available from spring and early summer collections to rule out the possibility of sexual maturity in smaller females, it seems that *N. funebris* females ordinarily reach approximately 100 mm SL before becoming sexually mature.

Yolked ova were counted for 3 large females: 104 mm SL- 184, 106 mm SL- 114, 119 mm SL- 192. These counts were obtained by dissecting out and counting the ova from one-half of the ovary and then multiplying by 2. These counts compare with 107 eggs in the ovaries of a 122 mm total length female *N. insignis* (Clugston and Cooper, 1960).

Acknowledgments

I wish to express appreciation to the Florida Game and Freshwater Fish Commission, and particularly to James M. Barkuloo, for making this collection available for study. This work was done under the direction of Dr. Royal D. Suttkus. He and Dr. Gerald E. Gunning critically reviewed the manuscript. The study was carried out during tenure of a National Aeronautics and Space Administration Predoctoral Fellowship at Tulane University.

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Manuscript received April 10, 1966.

SOME PHYSIOLOGICAL STUDIES ON TWO STRAINS OF THE GREEN ALGA *COELASTRUM MICROPORUM* NAEG.

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Abstract. — The effects of agar concentration, temperature, colchicine, and gibberellic acid on the growth and morphology of two strains (280 and 281, Univ. Indiana Algal Coll.) of *C. microporum* Naeg. were studied. Coenobial formation was observed to differ between the two strains as a result of these treatments and conditions.

Motile cells were produced by both strains and hypertrophy of cells grown in colchicine was observed.

Some comparative physiological studies of two strains (Nos. 280 and 281, Univ. Indiana Algal Coll.) of the colonial alga, *Coelastrum microporum* Naeg. show several differences between the two strains; i.e., size and length of time in coenobial form, the ability to utilize various substrates at various temperatures and the ability to grow heterotrophically. The investigations reported below encompass the following areas of investigation: (1) the effect of the alkaloid, colchicine, on growth and morphology, (2) the effect of gibberellic acid on growth and morphology, (3) the effects of solidity of media on coenobial formation, and (4) the apparent production of motile bodies by both strains.

Methods and Materials

All studies were made on organisms grown in a Bristol's medium as modified by Bold with glucose (10 g/1) added, and hereafter referred to as the medium. For the colchicine studies 150 ppm colchicine were added to the medium. Gibberellic acid was added to the medium at the rate of 10 mg/1. All cultures were grown in test tubes. The light source was a bank of fluorescent lights of about 400 fc. For studies on the effects of solidity of medium on the coenobial development, the cultures were grown in petri plates to which Bristol's and glucose (10 g/1) were added. Agar was added to this medium at the rate of 0.0, 1.5, 2.0, 2.5, and 3%.

An experiment was undertaken to determine the fate of certain motile bodies observed microscopically in various media on which these algae were cultured. Due to their small size pipetting proved impracticable so that a centrifuge technique was used. The procedure was as follows:

1. Examined known stock cultures of 280 and 281 to find a culture rich in these motile bodies.
2. Inoculated these cultures into a centrifuge tube of sterile distilled water.
3. Centrifuged, then with a sterile pipette removed one ml of supernatant.
4. Examined ½ of this portion on a slide for complete absence of vegetative cells and the presence of motile bodies.
5. Inoculated the remaining fluid on slants.

Results and Discussion

Colchicine. — Colchicine appeared to have an inhibiting effect on the production of coenobia. Both strains produced large single cells of bizarre shapes sometimes lobed and very granular in appearance. Rate of development in terms of numbers, however, did not appear to be affected. When some of these abnormally large cells were inoculated into fresh medium they reverted back to normal coenobial forms.

Gibberellic Acid. — Cultures were inoculated into the medium to which gibberellic acid had been added. (Table 1). The cultures were then grown heterotrophically at either 20°C or 36°C. Gibberellic acid appeared to stimulate growth and increase cell size at both temperatures. Strain 281, however, appeared to be extremely sensitive to this

concentration of gibberellic acid. After 8 weeks the cultures turned white, and upon transfer into the medium no growth occurred in the light. Culture 280 upon transfer grew abundantly under these same conditions. Thus these two strains appear to be differentially sensitive to gibberellic acid.

Effect of Solidity of Medium. — The cultures were inoculated into test tubes of medium and petri dishes of medium to which agar had been added at 0.0, 1.5, 2.0, 2.5 and 3.0%. The results obtained were opposite to those of Trainor and Hilton (1963). They reported an increment of coenobial formation corresponding to an increment of solidity of media. The percentage of coenobial formation in our experiments, however, decreased with an increase in solidity of media with the greatest percentage of coenobia occurring in liquid media.

Production of Motile Bodies. — When the present investigations with *Coelastrum* were begun a motile stage had not yet been reported in the literature. But our observations indicated that motile cells were being formed. Observations of cells (1500 X) showed very small apparently motile bodies present in the medium. These bodies were of such a size so as to be affected by Brownian movement. A drop of a mixture of HC1 and methylene blue was placed under the coverslip and as the front reached the bodies all movement of the type seen earlier stopped. Characteristic Brownian movement continued. These motile bodies have been seen inside the mother cell as well as in the media. They have been seen in various sizes which could represent various stages of development of zoospores and they have been seen leaving the mother cell as well. There appears to be a parallelism between yellowing of the cultures and motility. This yellowing occurs after 1 month in liquid medium and after 2 months on agar slants with the same medium at 400 fc illumination with a bank of fluorescent lights.

Following the procedure outlined under Methods and Materials for the determination of motile bodies, growth was observed after 48 days indicating that these motile bodies were probably a part of the life cycle. Though the results were positive the technique is open to criticism. Since this time a motile stage in *C. microporum* 280 has been reported (Trainor and Burg, 1965). Motility in *C. microporum* 281 has not hitherto been reported.

Literature Cited

Trainor, F. R., and C. A. Burg. 1965. Motility in *Scenedesmus dimorphus*, *Scenedesmus obliquus*, and *Coelastrum microporum*. J. Phycol. 1:15-18.

————, and R. L. Hilton. 1963. Culture and *Scenedesmus longus*. Bull. Torrey Bot. Club 90:407-412.

Manuscript received May 26, 1966.

Table 1. — Effects of 10 mg/1 of gibberellic acid on the growth and morphology of the two strains of *Coelastrum microporum*.

Strain	Glucose-gibberellic acid—Bristol's		Reinoculated into glucose and Bristol's, light—from tubes grown with gibberellic acid
	20°C	36°C	25°C
280	+++	++	++
281	++	+++	—
Remarks	Increased growth rate, Larger cells, 281 cells lost chlorophyll and became shrunken. 281 remained in coenobial form for a longer period of time.		280 survived and retained chlorophyll. 281—no growth of inoculum.

GROWTH OF *DIPLODIA ZEAE* IN SHAKER CULTURE

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ABSTRACT. — Using Czapek-Dox solution, *Diplodia zeae* grew best when initial pH levels were about 4.5. Mycelial dry weight increased with the addition of yeast extract to this solution. The growth-stimulating effect of yeast extract could not be replaced with ash of yeast extract. Fresh weights of mycelium grown in continuous light were greater than that grown in the dark. Growth of mycelium in light or dark did not appear to affect dry matter production.

Diplodia zeae (Schw.) Lev. causes seedling blight and ear, root and stalk rot of corn. There are relatively few reports regarding the factors affecting growth of this fungus in pure culture. Durrell (1913) reported that *D. zeae* grew well on a number of standard media such as cornmeal, oatmeal, and bean stems. Using synthetic media, he found that the fungus grew well on those with sucrose, dextrose, maltose, and lactose, but made slowest growth on the latter. Pure cellulose agar induced profuse growth and sporulation. Kinsel (1937) and Stevens and Larsh (1939) were able to grow the fungus in media with different carbon sources. Wilson (1942) also grew the fungus in media containing different carbohydrates and in different samples of the same carbohydrate. He obtained evidence that biotin might be a growth factor of *D. zeae*. Semeniuk (1940) reported that *D. zeae* grew poorly in Czapek-Dox liquid medium, plain agar, and glucose agar, but that the fungus grew better with additions of small amounts of water extracts of potato, carrots, and other organic materials. Biotin was not found to be a required growth substance.

This paper presents data on the effect of pH, yeast extract, ash from yeast extract, and light on the growth of *D. zeae* in shaker culture.

MATERIALS AND METHODS

A small piece of *D. zeae* and underlying potato dextrose agar was taken from near the edge of a rapidly-growing, four-day-old colony and was transferred to a 125 ml Erlenmeyer flask containing 50 ml of Czapek-Dox Broth (Fisher) liquid medium of pH 4.5 after autoclaving. All flasks were placed on a rotary shaker at 110 rpm with the temperature between 27-29°C.

To determine the effects of pH and light on growth, fragmented mycelium was grown for seven days in 50 ml of Czapek-Dox solution adjusted to give pH values of 3.5, 4.5, 5.5, 6.5, and 7.5 after autoclaving. Three flasks from each pH level were wrapped in aluminum foil and covered with a loose aluminum foil cap. These flasks were used for the dark treatment. Three other flasks from each pH level were used for a light treatment. In that group, aluminum foil caps were used to avoid any aeration differences in the two treatments. All flasks were agitated on a rotary shaker at 110 rpm under 300-foot-candles of illumination from Gro-Lux fluorescent tubes (Pappelis et al., 1964). The pH of the medium of all flasks was estimated daily using short range pH paper and drops of medium obtained with a sterile loop. The fresh and dry weights of the mycelium were determined after seven days of growth. Fresh weights were obtained after carefully washing and decanting three times with 50 ml of distilled water to remove all medium, filtering on a Buchner funnel, washing several times with water, and aspirating for three minutes after the final washing. Aspiration was with a Buchler Water Booster which provided a constant 40 psi for uniform aspiration. Dry weights were determined after 24 hours drying at 70°C.

The effect of yeast extract (Baltimore Biological Laboratories) on growth of

D. zeae was determined using 0.0, 0.1, 0.5, and 1.0 g of yeast extract per liter of Czapek-Dox solution. The pH of the media was adjusted to 4.5 since this pH gave good growth in previous experiments. In a separate experiment the fungus was grown nine days in Czapek-Dox media with ash from 0.5 g of yeast extract per liter and compared to growth in media with 0.5 mg yeast extract per liter of Czapek-Dox solution. Dry weight and pH were determined after 3, 4, 6, and 8 days of incubation. The mycelium was separated from the growth medium as described above.

Results and Discussion

The effect of light and pH on the fresh and dry weights of *D. zeae* mycelium are presented in Table 1. During the first 6 days of growth, the change in pH of the growth medium in the light and dark treatments were similar and, thus, only the pH values of medium in the light treatment are reported. Regardless of initial pH, growth medium in all treatments had changed to pH 6.8 by the fourth day and remained relatively unchanged thereafter. An increase to a higher pH was noted in the medium of the dark treatment by the seventh day.

Growth, as measured by fresh weight of the mycelium, was affected by both initial pH of the growth medium and by light. Estimates of the mycelial growth observed in the flasks during the 7 days indicated most rapid growth occurred in the low pH treatments in both light and dark. After 6 days, mycelial growth in the high pH treatments was similar in amount to that observed in the low pH treatments after one or two days of growth. However, the mycelium in the high pH treatments differed in appearance, being "milky" rather than forming round, loose colonies. Fresh weight of light-grown mycelium after 7 days of growth was greatest in the pH 4.5 medium; whereas, in the dark, the greatest growth

Table 1.—Daily Averages for pH of *Diplodia zeae* Growth Medium[1], and Final Fresh and Dry Weights of *D. zeae* Mycelium Grown in Czapek-Dox Solution in Light and Dark Treatments[2]. Each Average Represents 3 Flasks.

pH after autoclaving	Days after start of experiment											
	1	2	3	4	5	6	7					
							pH		g F wt		g Dry wt	
	pH	pH	pH	pH	pH	pH	L	D	L	D	L	D
4.5[3]	4.3	5.5	6.0	6.8	6.9	6.8	6.8	6.7	6.43	2.13	0.69	0.56
4.5	5.2	5.5	6.0	6.8	6.8	6.9	6.9	7.1	7.27	1.97	0.68	0.63
5.5	5.6	6.2	6.3	6.6	6.9	6.8	6.9	7.1	4.96	1.95	0.41	0.58
6.5	6.6	6.8	6.8	6.8	6.9	6.9	7.0	7.0	4.50	1.90	0.55	0.61
6.5[4]	6.9	7.0	6.9	6.8	6.9	6.9	6.9	7.3	3.70	1.80	0.62	0.63

[1] The averages of *D. zeae* growth medium pH for light and dark treatments generally varied ± 0.1 pH units during the first 6 days of growth. Thus, only the light treatment averages are reported.

[2] Dark treatment (D) was aluminum foil wrapped flasks with foil caps over cotton plugs; light treatment (L) was 300 foot candles of Grow-lux light with aluminum foil caps over cotton plugs.

[3] The pH 3.5 medium changed to pH 4.5 with autoclaving.

[4] The pH 7.5 medium changed to pH 6.5 with autoclaving.

was at 3.5. The amounts of fresh weight decreased when initial pH was increased in both treatments. Dry weight of mycelium grown in the light and dark did not differ greatly in the pH treatments except at pH 5.5.

When data concerning light and dark grown mycelium are compared little difference in dry weight production occurred but from 2 to 4 fold differences occurred in fresh weights, the greater gains occurring in the light. The greatest differences were observed in the lower pH treatments.

Similar differences in fresh weights of mycelium grown in light and dark were observed in earlier experiments with *D. zeae*. In those preliminary studies, the growth medium of the light treatment was observed to be more viscous than that of the medium in the dark and created problems during filtration and washing of the mycelium. The chemical nature of the viscous matter was not determined. Growth medium of dark treatments was easily filtered and presented no problem when mycelium was washed. In the reported experiment, the growth medium was diluted with 50 ml of distilled water and decanted three times before being transferred to the Buchner funnel for final washing under reduced pressure. In these conditions, mycelium was obtained relatively free from the viscous material. No other problems were encountered in this step to suggest that differences in fresh weights were due to external rather than internal moisture. The earlier work also showed mycelium dry weights to be greatest in the low pH treatments. From the data presented in this paper, it is possible that this was due to incomplete removal of the viscous material adhering to the mycelium.

Addition of yeast extract to the Czapek-Dox media resulted in greater mycelial dry weights (Table 2). Throughout the sampling period, dry weight as well as pH increased with increased amounts of yeast extract in the growth medium. The addition of 0.5 g of yeast extract per liter was considered sufficient to stimulate growth in future studies. In a separate study, ash of 0.5 g of yeast extract per liter of growth medium resulted in 160 mg of dry mycelium after 9 days of growth while 660 mg dry mycelium was obtained in medium containing 0.5 g of unashed yeast extract. This suggests that the growth factor for *D. zeae* in yeast extract is not a mineral nutrient. The nature of the stimulus from the organic matter contained is not known.

Robins et al. (1963) recently reported that the response of *Polyporus schweinitzii* Fr. to yeast extract or to the growth factors prepared from it was definitely affected by light. At high yeast extract levels, light-exposed cultures yielded higher dry weights than dark-grown cultures while the reverse was true at low levels of yeast extract. Growth of cultures in media containing ferulic acid instead of yeast extract was less in the light than in the dark except at high levels of this compound. When

TABLE 2.—Average pH of Medium and Dry Weight of *Diplodia zeae* mycelium Grown in Czapek-Dox Solution with Different Concentrations of Yeast Extract. Medium pH after Autoclaving was 4.5. Flasks were Wrapped in Aluminum Foil.

Yeast Extract g/l	Days after inoculation							
	2		4		6		8	
	pH	D Wt mg	pH	D Wt mg	pH	D Wt mg	pH	D Wt mg
0.0	5.2	10	5.9	78	6.1	149	6.1	146
0.1	5.9	77	6.4	213	6.6	273	6.6	280
0.5	6.2	104	6.5	265	6.7	328	6.9	450
1.0	5.9	137	6.7	345	6.8	422	7.1	505

sodium oleate, ferulic acid, and isoeugenol were added instead of yeast extract, the growth curves for the cultures grown in the light and dark were similar to those for yeast extract media under light and dark treatment. This was significant since oleic and ferulic acids were isolated from yeast extract. The dry matter yields obtained for *Poria ambigua* Bres. grown in light and dark was similar to that reported for *Polyporus schweinitzii* (Robbins and Hervey, 1960).

The observation of increased fresh weights for *D. zeae* grown in the light are unique to the work presented in this study. What role light-induced changes in *D. zeae* may play in the physiology of parasitism in root or stem rot of corn (Craig and Hooker, 1961; Koehler, 1960) remains for future studies.

Acknowledgment

This investigation was supported in part by National Science Foundation research grant GB-1072. Appreciation is expressed to Carolyn Sue Webb and Diane Tegtmeier for technical assistance.

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Manuscript received July 19, 1966.

SURVIVAL OF TRANSPLANTED YELLOW-POPLAR SEEDLINGS AND ROOT FOOD RESERVES

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Abstract. — Carbohydrate reserves in the roots of one-year-old yellow-poplar seedlings were not related to subsequent survival of the transplanted seedlings.

The ability of a seedling to produce new roots after being transplanted from the nursery affects its survival. A high carbohydrate content in the roots of a seedling at the time of transplanting could indicate a high capacity to supply energy necessary for the production of new roots. Previous investigations (Gilmore, 1962, 1964) have shown that food reserves in the roots of transplanted loblolly pine seedlings are not related to either survival or growth.

The results of a study to determine the effects of food reserves in roots of yellow-poplar (*Liriodendron tulipifera* L.) seedlings on subsequent survival are presented in this note.

Methods

A lateral root segment was removed from each of 85 one-year-old yellow-poplar seedlings; the seedling and root segment were numbered and the seedling transplanted in builders sand. The sand was well watered for one month after planting and then the plants were subjected to drought. When about one-half of the seedlings appeared to be dead, the sand was watered to field capacity and kept at this level for two weeks. At the end of this two week period, each plant was examined to determine if it was alive. A modified randomized procedure was used to select 24 dead and 24 living seedlings for the test.

Sugars and starches were determined on each lateral root segment of the 48 seedlings used in the test. Sugars were extracted with 80 percent ethanol and determined by the phenol-sulfuric acid method according to Dubois et al. (1956). Starches in the residues from the alcohol extract were extracted with amalyase and determined by the phenol-sulfuric acid method.

Results and Conclusions

Table 1 shows percentages of various carbohydrate fractions found in the two groups of seedlings. There are no statistical differences in the carbohydrate fractions between the living and dead seedling groups. The wide range in the

Table 1. — Levels of Carbohydrates, in Percent, in Roots of Yellow-poplar Seedlings when Lifted from Nursery.

	Reducing sugars		Other sugars		Starches		Total
	Average	Range	Average	Range	Average	Range	Average
Living seedlings group.....	5.30	2.75–9.42	1.14	0.46–3.11	12.75	3.99–26.75	19.19
Dead seedlings group.....	5.36	2.25–12.66	1.38	0.36–2.81	13.81	3.61–35.10	20.55

various carbohydrate fractions within the two groups substantiate results obtained with loblolly pine (Gilmore, 1964). From this experiment, it is concluded that root food reserves do not influence subsequent survival of transplanted yellow-poplar seedlings.

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Dubois, M., K. A. Gilles, J. K. Hamilton, P. A. Rebers, and F. Smith. 1956. Colormetric method for determination of sugars and related substances. Anal. Chem. 28: 350-356.

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Manuscript received July 23, 1966.

ACADEMY BUSINESS

SECRETARY'S REPORT FOR THE YEAR— APRIL 24, 1965 - APRIL 22, 1966

COUNCIL MEETINGS

The Council held four meetings during the year, as stipulated in the Constitution.

First Council Meeting.—The first Council meeting was held in the University Center, Northern Illinois University on Saturday morning, April 24, 1965, with President G. R. Yohe presiding. Thirteen persons were present.

Dr. A. D. Weaver, Second Vice-President, reported that 276 persons had registered for the 58th Annual Meeting.

Dr. E. C. Galbreath was reappointed Editor of the TRANSACTIONS.

Miss Joan Hunter was reappointed as the Chairman of the Planning Committee.

Dr. H. Eifert was reappointed as Chairman of the Educational Films Evaluation Committee.

Dr. C. Weatherbee was appointed as Chairman of the Junior Academy Committee, representing the Academy.

Dr. H. M. Kaplan was appointed Chairman of the Resolutions Committee.

Dr. R. M. Myers was appointed Chairman of the Nominations Committee.

Dr. O. Young was appointed Chairman of the Radio Discovery Committee.

Drs. W. M. Lewis and B. Musulin were reappointed to the Audit Committee.

Mr. A. R. Wildhagen was reappointed as the Academy's Publicity Advisor.

Dr. W. B. Hendrickson was reappointed as the Historian of the Academy.

Second Council Meeting.—This was held in the Conference Room of the Illinois State Museum, Springfield, on Saturday morning, November 13, 1965. Fifteen members and one guest, Mr. John Melvin of the Ohio Academy of Science, were present.

The topic of the relationship between the Junior Academy and the Senior Academy was discussed, including a discussion about the tax-exempt status of the Junior Academy.

The Historian reported that the Academy Archieves are now housed at the Illinois State Museum, Springfield.

Miss Joan Hunter, Chairman of the Planning Committee reported to the Council about her Committee's feasibility study regarding the establishment of a permanent central office for the Academy that would be administered by a full-time Executive Secretary. The proposed duties of the Executive Secretary would be to maintain a single membership list; be responsible for increasing Academy membership; handle Academy publications and fiscal activities; coordinate volunteer help; investigate sources of funds to support the Academy and submit proposals for grant money to support various Academy programs. Mr. J. Melvin provided information about the success that the Ohio Academy of Science has had with such an office. The Council voted to have the establishment of such an office for the Illinois Academy investigated further.

The Budget Committee's report for 1966 was received and accepted by the Council.

Dr. C. K. Hunt was appointed Chairman of the Science Talent Committee.

Third Council Meeting.—This was held in Felmley Hall of Science, Illinois State University, on Saturday morning, February 5, 1966. Twenty-four members were present.

Dr. Dale Birkenholz, Second Vice-President, reported that all the physical facilities for the 59th Annual Meeting had been reserved.

The Treasurer, Dr. W. C. Ashby, submitted his report for 1965 to the Council. The Council voted to accept the report and to authorize the Treasurer to pay the cost of an audit, by a CPA, of the Academy's finances.

Dr. H. H. Shoemaker was appointed as chairman of the Conservation Committee.

The Section Chairmen presented brief reports regarding the number of papers scheduled for each section at the Annual Meeting.

Fourth Council Meeting. — This meeting was held Thursday evening, April 21, 1966, at the Holiday Inn Motel, Bloomington, following a dinner at the motel. Twenty-seven members were present.

The Second Vice-President reported that the Geology Section had been cancelled and that the room for the Academy Banquet had been changed. The Section Chairmen reported that all preparations for the Annual Meeting had been completed.

THE 59th ANNUAL MEETING

General Meeting. — The general session of Friday morning, April 22, 1966, held in Room 133 of Felmley Hall of Science, was called to order by President G. R. Yohe.

Dr. Robert G. Bone, President, Illinois State University, gave the address of welcome. This was followed by a report on the Academy's Visiting Lecturer Program which was given by Dr. H. W. Gould.

The Presidential address, "A Dangerous Thing," was followed by two addresses dealing with pesticides. Dr. William H. Luckmann, Entomologist, State Natural History Survey, discussed "Pesticides—Use and Problems Associated with Corp Protection." Dr. B. J. Liska, Professor of Animal Science, Purdue University, talked about "Pesticide Residue Problems in Foods from Animal Sources."

On Friday evening, in the University Union, Dr. Edward L. Haenisch, Chairman, Department of Chemistry, Wabash College, Indiana, gave the Annual Public Lecture, "Johnny and Relativity."

On Saturday morning, April 23, Dr. J. L. Martens, Department of Biological Sciences, Illinois State University, conducted a botany field trip to the Lake Bloomington area.

Technical Sessions. — On Friday afternoon, April 22, the following papers were presented:

Anthropology

Room 232, Schroeder Hall
Robert L. Hall, Chairman
Illinois State Museum, Springfield

The Mississippian Period at Dickson Mounds, Fulton County, Illinois. Joseph R. Caldwell, Illinois State Museum, Springfield.

Determinants of Culture. Thorne Deuel, Illinois State Museum, Springfield.

In Defense of Midwestern Dendrochronology. Patrick J. Munson, University of Illinois, Urbana.

Cahokia and Carbon-14. Robert L. Hall, Illinois State Museum, Springfield.

Ecology and the Mississippians. Larry Bowles, Illinois State Museum, Springfield.

Botany

Section A
Room 222, Felmley Hall
Paul D. Voth, Chairman
University of Chicago, Chicago

A Suggested Mounting of "coal-ball peels." J. Louis Martens and A. T. Clausen, Illinois State University, Normal, and Western Illinois University, Macomb.

Comparative Study on the Frequency of Mitotic Phases in Digitonin and Colchicine Treated Plant Cells. Laszlo Hanzely and Leslie Olah, Southern Illinois University, Carbondale.

Some Aspects of *Psilotum* on the Hawaiian Islands. J. Louis Martens, Illinois State University, Normal.

Developmental Plasticity of the Angle Meristem of *Selaginella kraussiana.* John R. Yaeger, University of Chicago, Chicago.

Opportunities in Physiological Genetics provided by Albino Maize. J. Louis Martens, Illinois State University, Normal.

The Catalase and Peroxidase of the Anomalous Alga, *Cyanidium caldarium.* Joseph Cream, Chicago City Junior College, Loop Branch, Chicago.

Effect of Salinity and Temperature on the Germination of Halophyte Seed. Irwin A. Ungar, Quincy College, Quincy.

Quantitative Effect of Photoperiodic Induction on the Rate of Leaf Abscission in Debudded and Intact *Perilla* Plants. Donald R. Krizek, University of Chicago, Chicago.

Extranuclear Feulgen-positive globules in *Vicia faba.* James R. Bradshaw and Te-Hsui Ma, Western Illinois University, Macomb.

A Comparison of Respiratory Activity in Normal and Induced Adventitious Roots. Marvin C. Williams and Donald S. Galitz, Western Illinois University, Macomb.

Section B

Room 220, Felmley Hall
Orie J. Eigsti, Presiding
Illinois Teachers College,
Chicago-South

The Algal Flora of Illinois: Recent Contributions at Southern Illinois University. Kenneth L. Weik, Southern Illinois University, Carbondale.

Aquatic Plant Collecting in Illinois. Ben L. Dolbeare, Illinois State Museum, Springfield.

Woody Vegetation Survey of Baber Woods. John Ebinger and William McClain, Eastern Illinois University, Charleston.

Triploid Seedless Watermelon: Problems Solved and Unsolved. Orie J. Eigsti, Illinois Teachers College, Chicago-South.

Composition of an Upland, Streamside Forest in Piatt County, Illinois. J. W. Geis and W. R. Boggess, University of Illinois, Urbana.

Pine Growth and Some Related Site Factors on Sandy Soils in Western Illinois. W. R. Boggess and R. E. Monteen, University of Illinois, Urbana.

Stem Growth of a Shortleaf Pine at Six Locations Using the Fritts Dendrograph. A. R. Gilmore, University of Illinois, Simpson.

Chemistry

Room 436, Felmley Hall
David G. Rands, Chairman
Southern Illinois University,
Edwardsville Campus
Section A
Pesticides Symposium
Robert D. Stallard, Presiding
Southern Illinois University,
Edwardsville Campus

Biological Agents in the Control of Insects. E. S. Sharpe, Northern Regional Research Laboratory, Peoria.

The Chemical Basis of Interactions Between Pesticides, Drugs and Other Chemicals. Kenneth P. DuBois, Toxicity Laboratory, University of Chicago, Chicago.

The Effect of Metal Ions on the Toxicity of Octamethylpyroposphoramide. M. D. Joesten and R. A. Hill, Southern Illinois University, Carbondale.

Two Gardeners View of Pesticides. Carl Weatherbee and Walter Arthur Koch, Millikin University, Decatur.

Nox-Toxic Control of Pests and Plant Disease. J. David Larson, Normal Soil Inc., Hinsdale.

Section B

Room 438, Felmley Hall
William J. Probst, Presiding
Southern Illinois University,
Edwardsville Campus

Mannich Condensations Involving Resorcinols. I. The Condensation of Secondary Amines, Formaldehyde, and Resorcinols. Carl Weatherbee, John T. Hortenstine, Jr., and Linda Butler, Millikin University, Decatur.

The Ionization Constant of 2,4-Dinitrophenol as a Function of Temperature. William J. Probst and David G. Rands, Southern Illinois University, Edwardsville Campus, East St. Louis.

A Statistical Treatment of Screening. Shelba Jean Musulin and Boris Musulin, Southern Illinois University, Carbondale.

Electrophysiological Investigation of Chemoreceptors and a New Chemosensory Equation. Clarence W. Hardiman, Illinois State University, Normal.

The Born-Oppenheimer Correction for an Elliptic Potential. Charles Brown and Boris Musulin, Southern Illinois University, Carbondale.

The Polarography of Europium and Ytterbium. Hsiao-Shu Hsiung Chang and Joseph A. Rard, Southern Illinois University, Edwardsville Campus, East St. Louis.

Incorporation of C^{14} from Glucose-1-C^{14} in the Lipid Fractions of *Debaryomyces Hansenii*. Emanuel Merdinger, Roosevelt University, Chicago.

Conservation

2nd Floor Dining Room,
University Union
Hurst H. Shoemaker, Chairman
University of Illinois, Urbana

Great Horned Owl and Barred Owl on an Illinois River. Richard G. Bjorklund, Bradley University, Peoria.

The Effects of Logging on an Illinois River Heronry. Richard G. Bjorklund, Bradley University, Peoria.

Illinois Natural and Scientific Areas. Robert A. Evers, Natural History Survey, Urbana.

Status, Ecology, and Management of Prairie Chickens in Illinois. Ronald L. Westemeier, Natural History Survey, Urbana.

Efforts to Prevent the Extinction of the Prairie Chicken in Illinois. Glen C. Sanderson and William R. Edwards, Natural History Survey, Urbana.

Further Studies of the Life History of the Greater Prairie Chicken on the Cam-

pus of the University of Illinois. Hurst H. Shoemaker and Stanley Etter, University of Illinois, Urbana.

A Study of the Vocalization of Juvenile and Adult Greater Prairie Chickens. Jean Kuehl and Hurst H. Shoemaker, University of Illinois, Urbana.

Rearing and Release of Prairie Chickens in Cook County Forest Preserves. Charles A. Westcott, Forest Preserve District of Cook County, Barrington.

The Parasites of a Captive Flock of the Greater Prairie Chicken. Steven Spigarelli, State Natural History Survey, Urbana.

A Study of Food Preferences of the Greater Prairie Chicken in Captivity. Larry A. Von Behren and Hurst H. Shoemaker, University of Illinois, Urbana.

Geography

Section A

Room 230, Schroeder Hall Annex
Paul J. Brand, Chairman
Illinois State University, Normal

Sequent Occupance of a Cash Grain Farm in Central Illinois. Roger J. Barry, Eastern Illinois University, Charleston.

Woodlot Utilization in an Intensive Agricultural Area. George P. Stevens and B. Ross Guest, Northern Illinois University, DeKalb.

Present Status of Rural School Sites in East Central Illinois. Donald Arthur Tolen, Eastern Illinois University, Charleston.

Population and Distributional Changes of the White-Tail Deer in Illinois. Richard C. Rounds, Illinois State University, Normal.

Finish Settlement in the Upper Great Lakes States. Norman Moline, University of Chicago, Chicago.

Recent Migration of Amish Settlers into Southwestern Wisconsin. Dalias A. Price, Eastern Illinois University, Charleston.

Geography, Settlement, and Migration in United States History. M. B. A. Bruckner, Chicago City Junior College, Woodrow Wilson Branch, Chicago.

Some Aspects of Human Geography in the Soviet Union. Paul J. Brand, Illinois State University, Normal.

A Population Density Map of Africa. Paul F. Mattingly and Else Schmidt, Illinois State University, Normal.

An Evaluation of the Density Patterns of the Population Map in Africa. Else Schmidt and Paul Mattingly, Illinois State University, Normal.

Precambrian Metamorphics and Structures in the Northern Part of the Madison Mountains, Montana. James C. Carl, Illinois State University, Normal.

Section B

Room 116, Schroeder Hall
John E. Trotter, Presiding
Illinois State University, Normal

The Thermal Influence of Lake Ontario on Orchards Along its South Shore. Joseph Contessa, Southern Illinois University, Carbondale.

The Radiation Budget of the Colorado Front Range in its Relation to the Energy Balance of Mountain Terrain. David M. Sharpe, Southern Illinois University, Carbondale.

An Investigation of the Relationship between Meteorological and Technical Parameters and Corn Yields. John Lewis, Jr., University of Illinois, Urbana.

Soils Geography: A North Carolina Example. Paul W. Nausel, Eastern Illinois University, Charleston.

Industrial Density in Chicago. Donald Stetzer, University of Chicago, Chicago.

Migratory Labor in the Federal Republic of Germany. Peter Schulz, Illinois State University, Normal.

Meteorology and Climatology

Room 136, Felmley Hall
Douglas M. A. Jones, Chairman
Illinois State Water Survey, Urbana

A Tornado Disaster in Retrospect. Stanley A. Changnon, Jr., and Richard G. Semonin, Illinois State Water Survey, Urbana.

A Study of the Palm Sunday Tornadoes, 11 April 1965, with the Use of Radar. Dorothy L. Bradbury, University of Chicago, Chicago.

Detection of a Weak Front by WSR-57 Radar. George W. Polensky, U. S. Weather Bureau, Chicago.

The "Evapotron" and the Measurement of Eddy Fluxes in the Lower Atmosphere. Bruce B. Hicks, Argonne National Laboratory and Commonwealth Scientific Industrial Research Organization, Argonne.

Microbiology

H. H. Thornberry, Chairman
Department of Plant Pathology,
University of Illinois, Urbana

50th Year Commemorative Program for Thomas Jonathan Burrill, 1839-1916.

Section A

Room 114, Schroeder Hall
James H. Smith, Presiding
Department of Plant Pathology,
University of Illinois, Urbana

Mechanical Deaggregation and Disruption of Haploid Yeasts by Sonication. Curtis Scheifinger, Charles Gregg, and Maurice Ogur, Department of Microbiology and Biological Research Laboratory, Southern Illinois University, Carbondale.

Differential Staining of Nuclei of *Emericellopsis*. Bernard W. Benson, Rock Falls Twp. High School, Rock Falls.

Nutritional and Morphological Studies of the Genus *Coelastrum*. Leland O. Hansen, Mason G. Fenwick, and D. L. Lynch, Department of Biological Sciences, Northern Illinois University, DeKalb.

The Isolation, Culture, and Study of Some Keratinophilic Actinoplanaceae from Illinois Soils. Gilbert K. Boese and Darrell L. Lynch, Department of Biological Sciences, Northern Illinois University, DeKalb.

Numerical Analysis of Some Species of the Genus *Hansenula*. Nicholas Grecz and C. A. Lin, Department of Biology, Illinois Institute of Technology, Chicago.

Effect of Oxygen on Heat and Radiation Resistance of Spores of *Clostridium botulinum* 33A. T. Tang and N. Grecz, Department of Biology, Illinois Institute of Technology, Chicago.

The First Cell Division Lag and Survival of Frozen *Escherichia coli*. Frank E. Kocka and Harold W. Bretz, Department of Biology, Illinois Institute of Technology, Chicago.

Taxonomic Characteristics of a Yellow Bacterium Isolated from the Tissue of Jonathan Apple Trees. James H. Smith and Dwight Powell, Department of Plant Pathology, University of Illinois, Urbana.

Interrelationship Between Athiorhodaceae and Green Algae. Julius L. Heinis, Quincy College, Quincy.

Virus Diseases of Citrus. Frank J. Reynolds, Department of Biological Sciences, Western Illinois University, Macomb.

Heat Activation of Spores of *Clostridium botulinum* 33A. J. Upadhyay and N. Grecz, Department of Biology, Illinois Institute of Technology, Chicago.

The Effect of Temperature on Algal Growth. E. Warren Potter, Department of Science, Vincennes University, Vincennes, Indiana.

The Isolation and Identification of *Listeria monocytogenes*. Arden H. Killinger, College of Veterinary Medicine, University of Illinois, Urbana.

Section B

Room 115, Schroeder Hall
Jaswant Singh, Presiding
Department of Plant Pathology,
University of Illinois, Urbana

Termination of Immunologic Tolerence by Antigen-Antibody Complexes. F. E. Hemphill, D. Segre, and W. L. Myers, College of Veterinary Medicine, University of Illinois, Urbana.

The Influence of Certain Phenols in a Basal Medium Upon the Growth of Pathogenic Races (A-1 to A-8) of *Phytophthora fragariae* Hickman. H. S. Gill and Dwight Powell, University of Illinois, Urbana.

Utilization of Amino Acids as Sources of Carbon and Nitrogen by Species of *Hansenula*. Lynn Larsen, Kathleen Killick, Alice King, and L. R. Hedrick, Department of Biology, Illinois Institute of Technology, Chicago.

The effect of Light on the Amino Acid Metabolism of *Diplodia zeae*. Diane Tegtmeier and A. J. Pappelis, Department of Botany, Southern Illinois University, Carbondale.

Growth of *Diplodia zeae* in Shaker Culture. R. A. Katsanos and A. J. Pappelis, Department of Botany, Southern Illinois University, Carbondale.

Influence of H-ion Concentration on the Filterability of Tobacco Mosaic Virus Through Celite and Activated Charcoal Filter Cakes. Abdullatif B. Shawkat, Department of Plant Pathology, University of Illinois, Urbana.

The Steady State Growth Characteristics of Bacterial Colonies. L. D. Witter, S. A. Palumbo, and V. T. Rieck, Department of Food Science, University of Illinois, Urbana.

Pyocyanine Degradation by Apyocyanogenic Strains of *Pseudomonas aeruginosa*. Y. Azuma and L. D. Witter, Department of Food Science, University of Illinois, Urbana.

The Effect of Age on Substrate Permeability in *Rhizoctonia solani* and *Sclerotium bataticola*. Tom G. Obrig

and D. Gottlieb, Department of Plant Pathology, University of Illinois, Urbana.

Mechanism of Antifungal Action of Patulin. Jaswant Singh and David Gottlieb, Department of Plant Pathology, University of Illinois, Urbana.

Virus of Wheat Mosaic: Biovector Transmission. Mary Ruth Thompson and H. H. Thornberry, Department of Plant Pathology, University of Illinois, Urbana.

Viruses of Orchids: Etiology of Blossom Brown Necrotic Streak. Kermat Izadpanah, Mary Ruth Thompson, and H. H. Thornberry, Department of Plant Pathology, University of Illinois, Urbana.

Virus of Maize Dwarf Mosaic: Distribution and Severity in Illinois. H. H. Thornberry, Alan G. Otterbacher, and Mary Ruth Thompson, Department of Plant Pathology, University of Illinois, Urbana.

Physics

Room 223, Felmley Hall
Mashar Hasan, Chairman
Northern Illinois University, DeKalb

Dr. Mahlon Loomis, Discoverer and Inventor of Radio. Paper Number Four. Otis B. Young, Southern Illinois University, Carbondale.

Solar and Space Influences on Cosmic Rays. Otis B. Young, Southern Illinois University, Carbondale.

An Anti-Compton Gamma Ray Spectrometer. Robert C. Etherton, Southern Illinois University, Carbondale.

Small Quadrupole Mass Spectrometer. H. P. Johnson and M. Saporoschenko. Southern Illinois University, Carbondale.

Neutron Activation Analysis for Na and C1 in Cockroaches. Peter Tsao, Northern Illinois University, DeKalb.

The Role of Symmetry in Physics. Hyungsik Kim and Mazhar Hasan, Northern Illinois University, DeKalb.

Decay Scheme Studies of Ir^{192}, Sb^{124}, Tb^{160} and Ta^{182} with Lithium Drifted Detectors. D. Bushnell and M. Shaikh, Northern Illinois University, DeKalb.

The Variation Problem and He_2^+. Cherng-Maw Wang and Boris Musulin, Southern Illinois University, Carbondale.

Mobility of Mass Analyzed CO^+ and $(CO)_2^+$ ions in CO Gas. G. W. Bielak and M. Saporoschenko, Southern Illinois University, Carbondale.

Electrical Properties of Indium Oxide Single Crystals. Allen F. Hrejsa, Southern Illinois University, Carbondale.

Lie Algebras in Theoretical Physics. Mazhar Hasan, Northern Illinois University, DeKalb.

Science Teaching

Section A

Room 333, Felmley Hall
J. N. Cummins, Co-Chairman
Southern Illinois University, Carbondale

Keynote Address: Innovation and Curriculum Development . . . A Contrast. Paul Merrick, Webster College, Webster Groves, Missouri.

The Elementary School Science Project — Using Astronomy as a Central Theme. JoAnne Stecher, University of Illinois, Urbana.

Science Workshops for Elementary Teachers. Comments on Five Years' Experience. Lester Taylor, Office of Superintendent of Public Instruction, Springfield.

Developing Science Skills via the Inquiry Approach. Audrey Tomera, West Jr. High School, Kankakee.

Investigations in Science Skills Development in the Junior High School. Harold Hungerford, Southern Illinois University, Carbondale.

Gases and Airs. A Video tape of the "New Science" in Action in an Intermediate Grade Classroom.

Section B

Room 327, Felmley Hall
Otto Ohmart, Co-Chairman
Southeast Missouri State College, Cape Girardeau

Vapor Pressure Osmometry of Biological Fluids. Vincent J. Sawinski, Loyola University, Chicago.

Controlled Self-pollination in *Zea mays* (Single Concept Film). J. Louis Martens and Harry O. Jackson, Illinois State University, Normal.

A New Method to Illustrate DNA Replication. RNA Formation, and Protein Synthesis. Daniel G. Hance, Frederick C. Hill, J. R. Carlock, and H. A. Moore, Illinois State University, Normal.

Multifunction Diffusion Chamber. Joyce Rada Emery, J. R. Carlock, and H. A. Moore, Illinois State University, Normal.

An undergraduate Biological Curriculum based upon the CUEBS Study. Wayne W. Wantland, Illinois Wesleyan University, Bloomington.

Teacher Preparation for Implementing the "New Science" Curricula. J. N. Cummins, Southern Illinois University, Carbondale.

Plant Nutrients in Controlled Plant Growth Chambers. William Schwab, Joliet Twp. High School and Junior College, Joliet.

ZOOLOGY

Section A

3rd Floor Lounge, University Union

Lester C. Shell, Chairman

Millikin University, Decatur

Chemical Influence on Radiation Induced Chromosome Loss. Sidney Mittler and Raymond U, Northern Illinois University, DeKalb.

The Effect of Mating Frequency on the Recovery of Radiation XO Males in *Drosophila melanogaster*. Raymond U, James Overley, and Sidney Mittler, Northern Illinois University, DeKalb.

The Varying Weights of Laysan Albatrosses (*Diomedea immutabilis*). Harvey I. Fisher, Southern Illinois University, Carbondale.

Incidence and Ecology of Oral Protozoa in Man. Wayne W. Wantland, Illinois Wesleyan University, Bloomington.

Serological Studies with the Domestic Chicken. I. Electrophoretic Separation of Serum Proteins. Carl Coan and Jack Bennett, Northern Illinois University, DeKalb.

Effects of Temperature on Some Aspects of the Cardiovascular System in Turtles. E. C. Gasdorf, Bradley University, Peoria.

Behavioral Genetics of *Drosophila melanogaster*. I. Selection for maze transit rate. Jack Bennett and Ronald Capek, Northern Illinois University, DeKalb.

Retention of Radioactivity in Various Organ Systems of White Mice. Lester C. Shell, Denzil Hawes-Davis and Sam McClugage, Millikin University, Decatur.

The Fine Structure of the Coelomocytes of *Cucumaria californica*. Howard R. Hetzel and Mathew Nadakavukaren, Illinois State University, Normal.

The Effects of Flooding of the Mississippi River on Populations of *Peromyscus leucopus*. George H. Schneider, Quincy College, Quincy.

Section B

Room 304, University Union

Frederick A. Giere, Presiding

Lake Forest College, Lake Forest

Pepsinogen Response to Stress in the Cottontail Rabbit. Otto Bohrmil Brdlik, Bradley University, Peoria.

A Pleistocene Herpetofauna from Northwestern Georgia. J. Alan Holman, Illinois State University, Normal.

Serological Studies with the Domestic Rabbit. I. Electrophoretic Analysis. S. Robert Young and Jack Bennett, Northern Illinois University, DeKalb.

The Western Harvest Mouse (*Reithrodontomys megalotis*) in Central Illinois. Dale E. Birkenholz, Illinois State University, Normal.

The Probable Pleistocene Wanderings of Three Winter Stoneflies (Plecoptera). Herbert H. Ross and George L. Rotramel, State Natural History Survey, Urbana.

Incubation of Shelled Avian Eggs. I. Gas Exchange. John Elliott and Jack Bennett, Northern Illinois University, DeKalb.

The Host of *Oenonogastra* (Hymenoptera: Braconidae). Garland T. Riegel, Eastern Illinois University, Charleston.

The Life History of a Common Pond Dragonfly. Robert E. Groos and Charles J. Rohde, Jr., Northern Illinois University, DeKalb.

The Application of a New Chemosensory Equation to Some Psychophysical Data. Clarence W. Hardiman, Illinois State University, Normal.

Section C

Room 308, University Union

Robert Weigel, Presiding

Illinois State University, Normal

Medicinal Effects on Rate of Respiration and Distribution of Body Compounds in Reserpine Treated Mice. Lester C. Shell, Sam G. McClugage, Joe Kelliher, and William Sill, Millikin University, Decatur.

The Interrelationship of Heterotrophic Euglena and Bacteria. Evelyn Drewes, College of St. Francis, Joliet.

Changes in the Livers of Mice Fed Polyoxyethylene Sorbitan Derivatives. James N. Tone, Illinois State University, Normal.

Community Structure of Benthic Macroinvertebrates in an Intermittent Stream Receiving Oil Field Brines. B. J. Mathis, Bradley University, Peoria.

Utilization of D-amino Acids for Growth by *Drosophila melanogaster* Larvae. B. W. Greer, Knox College, Galesburg.

Effects of Vitamin D_2 on Calcification of Trichina Cysts in Hamsters. Steven L. Lawrence, Illinois Wesleyan University, Bloomington.

THE ANNUAL BUSINESS MEETING

The Business Meeting was called to order at 5:00 P.M., April 22, 1966, in Felmley Hall of Science, Illinois State

University, Normal, by President G. R. Yohe. Approximately 70 members were in attendance.

Reports of Officers. — President Yohe reported that the Council and the Planning Committee had spent the past year determining the feasibility of establishing a central office with a full-time Executive Secretary for the Academy. A motion was made and passed to empower the Council to continue its study of this matter. Treasurer Ashby presented his report for fiscal 1965, published herewith, and a motion was made and passed that his report be accepted.

Reports of Standing Committees: — Dr. R. J. Miller, Chairman of the Research Grants Committee recommended that the following grants be awarded:

Dr. William S. Courtis — $415.00. Southern Illinois University. Equipment for cytochemical interferometry of aging cells.

Dr. J. A. Ward — $127.00. Illinois State University. Equipment and fish for the study of parental and the young-to-parental behavior of the orange chromide.

Dr. E. R. Willis — $200.00. Illinois State University. Equipment for a study of sexual behavior of male cockroaches.

Dr. Clarence W. Hardiman — $232.00. Illinois State University. Equipment for a study of chemoreception.

Dr. Thomas J. Stachnik — $300.00. Illinois Wesleyan University. Equipment for a study of intracranial stimulation.

Mr. John M. McCleary — $76.00. Proviso West High School, Hillside. Supplies for a study of Acrasieae.

Dr. Miller recommended that any equipment purchased should remain the property of the institution where the recipient is working and that a copy of the grant announcement to the recipient be sent to his department head or principal.

A motion was made and passed to approve the grants and recommendations.

Reports of Special Committees: — Miss Joan Hunter, Chairman of the Planning Committee, read to the members the proposed constitutional amendments to Article VIII.

Section 2 was to be modified as follows: "The affairs of the Junior Academy shall be conducted in accordance with policies and principles determined by the Council of the Academy and the Executive Council of the Junior Academy."

Section 3 was to be eliminated.

Section 4 was to be eliminated.

Miss Hunter made the motion, seconded by Douglas M. A. Jones, that the amendments be accepted. Motion passed.

Miss Hunter then proposed a change in Article II, Section 3, of the By-laws, so as to delete the phrase "a representative of the Junior Academy." Her motion, seconded by Mr. G. H. Boewe, was passed.

Dr. H. M. Kaplan, Chairman of the Resolution Committee, submitted the following resolutions; all were approved by the Academy:

1. APPRECIATION TO THE HOST — *Whereas* many members of the Administration, Faculty and Staff of the Illinois State University have been responsible for the arrangements essential to the Fifty-nith Annual Meeting of the Illinois State Academy of Science, *Be it resolved* that the Academy express its gratitude to all who have participated in any way in arranging this Annual Meeting, and especially to:
   Dr. Robert G. Bone, President of the University;
   Dr. Dale E. Birkenholz, Second Vice President of the Academy, in charge of local arrangements.
   Be it further resolved that the Secretary be directed to send copies of this resolution to those specifically named.

2. APPRECIATION OF SERVICE — *Whereas* responsibility has been accepted by Dr. J. Louis Martens of the Department of Biological Sciences, Illinois State University, for arranging the Botany Field Trip, which constitutes a significant portion of the program for the Fifty-ninth Annual Meeting of the Academy, *Be it resolved* that the Academy express its thanks to Dr. Martens for organizing and conducting the Field Trip, and *Be it further resolved* that the Secretary be directed to send a copy of this resolution to Dr. Martens.

3. APPRECIATION OF SERVICE — *Whereas* Dr. Willard Gersbacher has served the Academy in a most diligent and highly productive manner as President of the Junior Academy of Science, *Be it resolved* that the members of the Academy express their appreciation for his service, and that the President be directed to send him a letter of commendation.

4. MILITARY RECLASSIFICATION OF GRADUATE STUDENTS IN SCIENCE AND ENGINEERING — *Whereas* qualified graduate students working for their Master's or Doctor's degrees in science and engineering in American universities are now being called for induction into the military service, and *Whereas* there is a great need for graduate students in science, and *Whereas* the graduate students have their careers interupted to fill local quotas near the culmination of 20 or more years of formal training, and *Whereas* this action represents a poor utilization of scarce and nationally needed talent and is not in the best interest of our country, and *Whereas* a dearth of scientists may severely injure our country in the future as all the battles are not being fought in Southeast Asia and our essential reserve of scientific strength can be depleted, *Be it resolved* that the graduate students in science and engineering be reclassified during the period of their training so that they may continue to serve our country and our free society by perfecting their scientific and technical skills for optimal use, and *Be it further resolved* that the Secretary be directed to send copies of this resolution to the National Director of Selective Service and to the Scientific Manpower Commission in Washington, D.C.

5. ANIMAL CARE LAWS — *Whereas* there are about 29 bills in the National Congress concerning legislative restrictions on biomedical research, and *Whereas* many of these bills seriously and acutely threaten to impede the use of laboratory animals, and *Whereas* it now seems necessary for the scientific community to press for constructive legislation based on scientific standards of animal care without harmful restrictions on research, and *Whereas* the Roybal bill (H.R. 5191) contains a positive statement of attitudes that the public and scientists should maintain toward medical research and laboratory animal care, and *Whereas* the Roybal bill does not provide for damaging, restrictive federal legislation, and *Whereas* the Roybal bill states that animals are essential in research, provides for federal grants for research and training in laboratory animal health, care and use, and for the establishment of committees of experts on the subject, and *Whereas* the Roybal bill is backed by the National Society for Medical Research which represents about 1100 scientific organizations, *Be it resolved* that the Academy endorse the favorable reaction of the scientific community to the Roybal bill as it now reads, and *Be it further resolved* that the Secretary be directed to send copies of this resolution to representatives and senators from Illinois in the National Congress.

6. CONCERNING THE DISCOVERER OF RADIO — *Whereas* the Radio Discovery Committee of the Illinois State Academy of Science has found authoritative documentary evidence that Dr. Mahlon Loomis, an American dentist of Washington, D.C., performed successful experiments in aerial wireless telegraphic communication in 1864, and *Whereas* this communication system was publically demonstrated by Mahlon Loomis between two mountain peaks 14 miles apart in the Blue Ridge Mountains of Virginia in 1866 and was repeated before members of Congress in 1868 and was repeated many times thereafter by him and other persons, and *Whereas* the first patent issued in wireless telegraphy by the U. S. Patent Office was to Mahlon Loomis (Patent No. 129,971, dated July 30, 1872), and *Whereas* the Loomis Aerial Telegraph Company was chartered by the U. S. Congress in 1873 to increase its assets within a two-million dollar limit, and *Whereas* no evidence has been found that any other person antedated Mahlon Loomis in the use of radio or wireless telegraphic communication, and *Whereas* the Southern Illinois University Chapter of Sigma Pi Sigma, a National Physics Honor Society, on April 21, 1964 unanimously passed a resolution acclaiming Mahlon Loomis the inventor of radio communication, and *Whereas* the Physics Section of the Illinois State Academy of Science in its annual meeting April 24, 1964, except for two persons who did not vote, unanimously passed a resolution acclaiming Mahlon Loomis the inventor of radio communication, and *Whereas* a Mahlon Loomis Scientific Foundation has been incorporated in Washington, D. C. to further scientific research and to memorialize Mahlon Loomis

as the inventor of wireless telegraphic communication, and *Whereas* two bills, Senate Joint Resolution 111 and House Joint Resolution 685, are now pending in the U. S. Congress to memorialize Doctor Mahlon Loomis, *Be it resolved* that the Illinois State Academy of Science commend the proponents of these bills in the National Congress, with the statement that the evidence seems increasingly convincing for the priority of Dr. Loomis in the discovery of radio or aerial wireless telegraphic communication, and *Be it further resolved* that the Secretary of the Academy be directed to send copies of this resolution to all national congressmen and senators from the State of Illinois and to the proponents of Senate Joint Resolution 111 and House Joint Resolution 685.

7. APPRECIATION OF CONTRIBUTION TO ARCHAEOLOGICAL KNOWLEDGE — *Whereas* the Jones and Laughlin Steel Corporation has of their own initiative made possible a survey of their new plant site at Hennepin, Illinois, to preserve the significant archaeological information of the area before the construction of their proposed steel plant, and *Whereas* they have requested the Illinois State Museum through its Department of Anthropology to make the survey, *Be it resolved* that the Academy express its appreciation to the Jones and Laughlin Steel Corporation for their important action in making possible the preservation of archaeological materials and data as a contribution to scientific knowledge, and *Be it further resolved* that the Secretary be directed to send a copy of this resolution to the Jones and Laughlin Steel Corporation through Mr. Charles M. Beeghly, Chairman of the Board.

8. REARING AND RELEASE OF GAME SPECIES — *Whereas* the Illinois State Department of Conservation has announced a policy of phasing out the practice of rearing and releasing of game species except in State Public Shooting Areas because of ecological disturbances, high cost, small return, and tendency for the spread of disease, and *Whereas* the State Department of Conservation is currently evaluating, by the banding of released quail, the effectiveness of the present quail rearing program, and *Whereas* the Illinois Chapter of the Wildlife Society has by resolution commended the Department of Conservation for this action, *Be it resolved* that the Academy endorse the action of the State Department of Conservation for its proposed policy, and *Be it further resolved* that the Secretary be direced to send copies of this resolution to the Director of the Illinois State Department of Conservation and to the Governor of the State of Illinois.

9. NECCROLOGY—*Whereas* during the past year the Academy has lost by death Charles L. Bieber, Virginius H. Chase, Ivan S. Cliff, Charles C. Colby, J. J. Davis, V. O. Graham, Norman Hedenberg, Lillian Olga Hirsh, Ben C. Sher, Irvin L. Sparks, Lewis H. Tiffany, Annie L. Weller, and Bertrand A. Wright, *Be it resolved* that the Academy give expression to its sorrow for the deceased members by rising for a moment of silence.

Anthony E. Liberta
Secretary

TREASURER'S REPORT

January 1-December 31, 1965

TREASUER'S REPORT—JANUARY 1-DECEMBER 31, 1965

Checking account balance Dec. 31, 1964		$10,613.21	
Added to savings and loan accounts Feb. 1, 1965	$6,000.00		
Carried forward in checking account from 1964			$4,613.21
Income		7.071.01	
Dues	4,968.00		
Regular 1965	$1,805.00		
Regular 1966	2,966.00		
Student 1965	42.00		
Student 1966	50.00		
Emeritus 1966	5.00		
Life	100.00		
Library subscriptions	409.00		
Annual meeting registration fees	137.00		
AAAS research grants	864.00		
Renewal—U.S. Bond	2.81		
Interest—U.S. Bonds	138.45		
Interest—Savings & Loan Accounts	551.25		
Sale of publications	.50		
Expenditures		6,518.25	
AAAS Research Grants	864.00		
Council	240.47		
Editor's Office	161.69		
Frank Reed Memorial Prize	50.00		
Honoraria	350.00		
Librarian	353.25		
Miscellaneous	254.09		
Publications	2,670.00		
Science Talent Search	391.20		
Secretary's Office	651.89		
Treasurer's Office	531.66		
Net Income for 1965			552.76
Unexpended balance in checking account Dec. 31, 1965			$5,165.97
Cash in account		5,182.84	
Outstanding Check		16.87	

Statement of Assets Dec. 31, 1965

Unexpended balance in checking account		$5,165.97
Permanent Fund		2,150.00
U.S. Bonds	$1,700.00	
Carbondale Sav. & Loan Acct. #3522	450.00	
Reserve Funds		16,350.00
U.S. Bonds	1,800.00	
State Sav. & Loan Acct. #435	9,000.00	
Carbondale Sav. & Loan Acct. #3522	5,550.00	
Frank Reed Memorial Fund		1,329.96
Balance carried forward Jan. 1, 1965	1,275.19	
Interest during 1965	54.77	
Total Assets		$24,995.93

William C. Ashby,
Treasurer

OFFICERS AND STANDING COMMITTEE NOMINEES FOR 1966-67

President: Norman D. Levine, University of Illinois, Urbana.

First Vice President: Milton D. Thompson, Illinois State Museum, Springfield.

Second Vice President: William Cloud, Eastern Illinois University, Charleston.

Secretary: Anthony E. Liberta, Illinois State University, Normal.

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EDWIN C. GALBREATH

Southern Illinois University, Carbondale

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